A computational architectural design model based on fractals

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The journal of an association of institutes concerned with the quality of built environment. The publishing framework is shaped around the forces which act on built environment, which maintain, change and transform it. The content consists of articles which deal with these issues and in particular with responsive, self-sustaining and re-usable environments which have the capacity to respond to change, provide user choice and value for money.

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To achieve its aims, the OHIA organizes and co-ordinates a number of activities which include the publication of a quarterly journal, and, in the near future, an international seminar and an annual competition.
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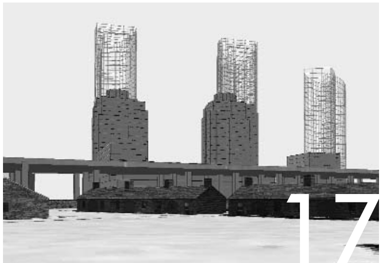

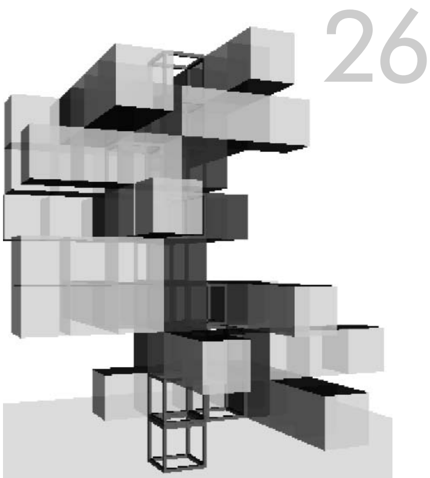

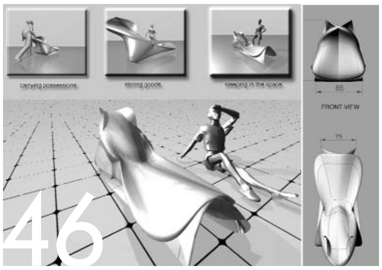

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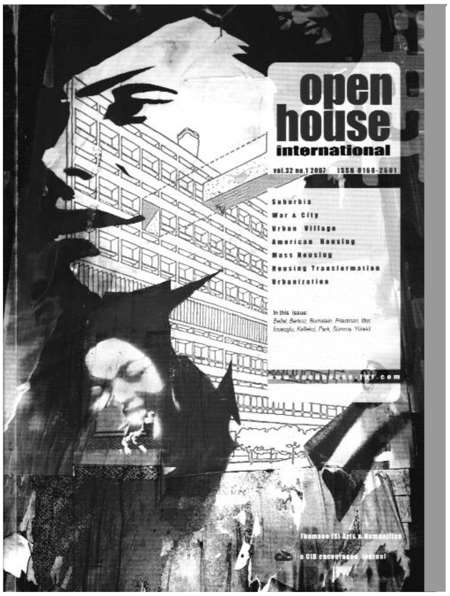

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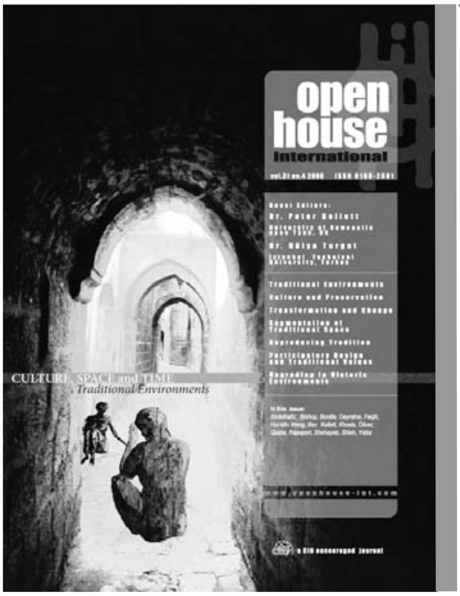

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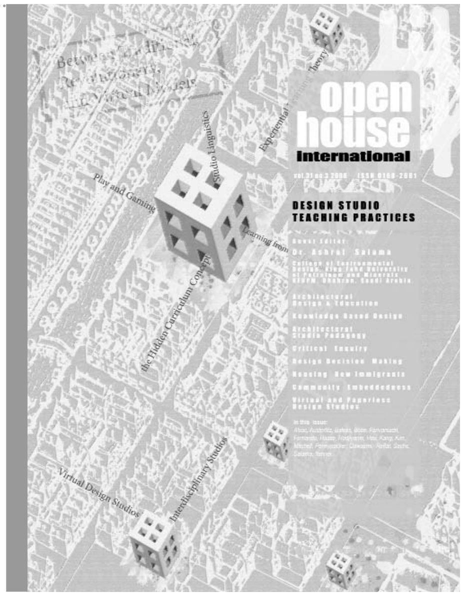

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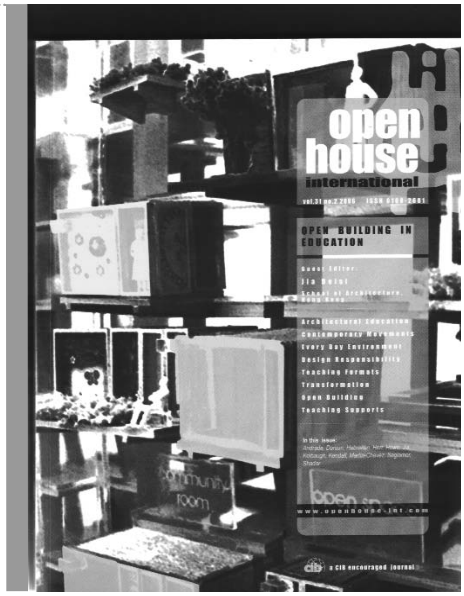

Karim Hadjri & Jamal Al-Qawasmi

ARCHITECTURE IN THE DIGITAL AGE: The effect of digital media on the design, production and evaluation of the built environment

The influence of digital media and information technology on architecture is increasingly evident. Architectural design, practice, fabrication and construction are increasingly aided by and dependent on digital technology. The proliferation of computers and telecomputing in design education and practice has resulted in a major paradigm shift and a reorientation in theoretical and conceptual assumptions considered to be central to traditional design education and practice.

Information technology has become ever more pervasive in architectural education and practice, and has revolutionised the way we design, practice, evaluate, teach and produce architecture. Digital technology has reconditioned the design process and how we operate as architects. The introduction of new computational tools to architectural design pushed the limits of conventional design models and methods. From inception to representation of designs, and from production to life-cycle management of buildings, architects had to develop novel approaches.

Architectural practice is becoming increasingly digitally driven, which is illustrated by the stunning architectural forms. This could not have happened without a radical change in the design philosophy that started with an increase in the use of digital media for design development and manufacturing rather than just representation. As noted by Kolarevic (2003) "The use of digital modeling (3D) and animation (4D) software has opened new territories of formal exploration in architecture, in which digitally-generated forms are not designed in conventional ways." Additionally, digital architecture has recently incorporated Smart Geometry and algorithms in Artificial Intelligence to name a few. This breathtaking digital development has also contributed to the creation of 'intelligent buildings' that are energy efficient and environmentally-friendly.

The digital age has also radically reconfigured the relationship between design and production, creating a direct digital connection between what can be imagined and designed and what can be built through "file-to factory" processes of computer numerically controlled (CNC) fabrication (Kolarevic 2003). The ability to generate construction information directly from design information is one aspect of digital architecture. Architectural design information is slowly becoming building information particularly with the emergence of Virtual Building solutions, and Building Information Modelling (BIM) in particular. In fact, BIM implementation could streamline the design and construction processes, and eventually may lead to the re-establishment of the architect as the master-builder.

The evaluation of the built environment has also relied on digital tools for control and diagnostics of building components or systems, such as post-occupancy evaluations and building performance modelling, which are effectively tested and validated using computer models.

Digital technology also radically changed the way we teach and learn architecture (Gross and Do 1999, Al-Qawasmi 2005). New computerized studios such as the paperless studio and the virtual design studio have been introduced in many architectural schools as new ways of practicing and teaching architectural design. Recent developments to computer networks are offering further opportunities for collaborative work and knowledge transfer at the global scale. Certainly more digital innovations and developments are to follow making a prediction on how architectural education and practice will be in a few decades incredibly difficult.

It is evident that digital media has fundamentally changing the way we design, practice, and produce architecture. These changes have given rise to a discourse and debate on the relationship between digital technology and architecture. Despite the extensive literature on the subject, the impact of digital technology on how we design, practice, teach, fabricate and produce architecture has not been sufficiently examined. This special issue of Open House International-OHI attempts to shed light on how digital media affects the design, production and evaluation of the built environment as well as how they challenging some of the fundamental assumptions, theories and practices of traditional architectural design education and practice.

More than forty five scholars from a diverse community of researchers responded with abstracts to a call for contributions specifically for this special issue of OHI, and twenty nine authors submitted papers for blind review. The eight papers selected for this special issue have the potential to broaden our knowledge and understanding of the impact of digital technology on architecture. These papers reflect key issues within the digital architecture study field: low cost virtual reality aided design (Tang and Yang), visualization for citizen initiated public participation (Lindquist), systematic analysis of CAAD education

(Pektas), cultural implications of applying virtual design education (Al-Qawasmi), digital media instruction in architecture education (Angulo), design exploration using a shape grammar with a genetic algorithm (Day), design generative models based on fractals (Ediz and Cagdas), and finally intelligent agent-based information handling (Chen)

Both the paper of Mark Lindquist, and the paper of Ming Tang and Dihua Yang examine the issue of real-time digital visualisation in architectural design. However, each addresses the issue using different context and tools. While Ming Tang and Dihua Yang examine the issue of real-time visualization and its influence on the architectural design process, Mark Lindquist address the impact of digital visualization on citizen initiated public participation process. Ming Tang and Dihua Yang report on using Low Cost Virtual Reality Aided Design (LC-VRAD) in architectural design. The paper explores the benefits and constraints of implementing LC-VRAD methods in various design phases such as site analysis, schematic design, design development, and the final design presentation. The paper highlights three main issues: how to use game engine in the studio environment; how to integrate VR into the design process, not only as a visualization tool, but also as a design instrument; and finally how to evaluate different methods of representing architectural models based on the efficiency of workflow, rendering quality and users' feedback.

Mark Lindquist, on the other hand, examines the impact of using digital technology on citizen initiated public participation process. The paper argues that digital visualization, and particularly real-time immersive technology, allows for far more effective communication of design spatial issues than conventional media offer, thus empowering the public by bridging the public-professional communication gap. The paper emphasizes that in public initiated dialogue the issues of validity, reliability and ethics are placed at the forefront of the discussion, and thus greatly increasing the scrutiny placed on both the technology and those preparing and presenting the visualization.

In an effort to integrate digital media in the design studio and to augment studio instruction, there has been extensive application of computers and information technology in design education, particularly in the past decade or so. The pervasiveness in the use of digital technology in architectural design education has also resulted in major changes in how architecture is being taught and learned (Al-Qawasmi 2005, 2006. The impact of digital media on architectural design education is the concern of three papers by Sule Tasli Pektas, Jamal Al-Qawsmi, Antonieta Angulo.

Compared to other areas of architectural research, CAAD is lacking in both definition and structure (Hanna and Barber, 2001). Sule Tasli Pektas address this gab by proposing a comprehensive, structured framework to study and analyze CAAD education. The proposed approach analyzes CAAD education from four different perspectives: objectives (why), contents (what), methodology (how) and management (who). It also provides a systematic way to evaluate CAAD at four different knowledge and disciplinary levels (viewpoints): sociological, ideological, epistemological, and pedagogical.

Al-Qawasmi paper examines the new paradigm of teaching and learning design virtually and the possible cultural implications of its implementation in developing countries such as the Arab states. The paper argues that information technology tools and virtual design environments (VDE) bring both opportunities and challenges for developing countries, and thus should be carefully examined. The paper concluding that implementing virtual design education in developing countries that share similar cultural values as the Arab states may have numerous advantages such as openness to regional (sub)cultures and their architectural traditions; promoting national identities and regional identifications and associations; and promoting localism and regionalism.

Antonieta Angulo presents a structured collection of case studies from the College of Architecture at Texas A&M University, one of the largest architectural schools in the United States that has long experience in the application of computer technology in the teaching and practice of design. These case studies were organized around the core discussion of how to address the subject of digital media and their incorporation in design curricula in schools of architecture. The paper examines the issue of "when", "what" and "how" we teach digital media and digital design, and the issue of developing multimodal and media-rich design environments.

Generative design systems are relevant to contemporary design practice in a variety of ways. Their integration into the design process allows the development of novel design solutions, difficult or impossible to achieve via other methods (Caldas and Norford 1999). Alan Day, and Özgür Ediz and Gülen Cagdas papers examine generative design as an approach to enable designers in the early design stage. However, they address the issue of generative design from two different perspectives. While Day

uses generative approach that utilizes shape grammar and genetic algorithm, Ediz and Cagdas use fractal geometry concepts.

In his paper, Design Exploration Using a Shape Grammar with a Genetic Algorithm, Alan Day suggests a generative approach based on shape grammar and genetic algorithms. Although the idea of linking a shape grammar to a genetic algorithm is not new, this paper proposed a novel way in which this might be done; by using the shape code as the genotype. The paper reports on Shape Evolution, a prototype generative design program. Shape Evolution allows for the definition of a design space by using a shape grammar, and only searches for solutions inside this space. This approach provides a way of creating a range of potential solutions to a design problem which fit with the designer's stylistic agenda. An interesting aspect of the proposed approach is using a shape code, which describes the steps that the shape grammar has taken to create each design.

Özgür Ediz and Gülen Cagdas, on the other hand, present generative design approach that relies on the fractal dimensions of an existing architectural pattern. Such a fractal geometry-based generative approach aims to enable the designer to create and explore new architectural forms that ensure the continuity of the existing architectural language. In addition the paper examined fractal concepts that appeared through "Chaos Theory" and how they affect contemporary architectural design.

Intelligent agent-based information handling is new research area and one of the most important topics in the field of artificial intelligence and its application in architecture and the built environment. The focus of this research is to achieve an Intelligent Environment (EI), a physical environment capable of natural human interactions, and that provides both proactive and reactive services to a community of users (Chun Mo 2002). Using intelligent agents to establish a smart open house system is the concern in the last paper of the collection by Shang-Yuan Chen. Chen's paper presents a smart open house system that utilizes an agent-based smart skin. The smart skin achieves adaptive actions that respond to users' lifetime needs by collecting environmental information through sensing devices. Such agent-based adaptive actions are based on fuzzy logic inference and neuro-fuzzy learning processes. The paper argues that such smart lifetime (or ageless) home will be highly needed to serve the aged society that will emerge in Taiwan by 2020.

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REFERENCES

AL-QAWASMI, J. 2006, "Transformations In Design Education: The Paperless Studio and the Virtual Design Studio," *Open House International,* 31 (3), pp. 95-103.

AL-QAWASMI, J. 2005, "Digital Media in Architectural design education: reflections on the e-studio pedagogy," *Art, Design & Communication in Higher Education,* 4(3), pp. 205-222.

CALDAS, L. and NORFORD, L. 1999, A genetic Algorithm Tool for Design Optimization, *In Proceedings of ACADIA 1999,* pp. 260-271.

CHUN MO, ZHENG 2002, Intelligent Buildings and Intelligent Agents--A Human-Centered Framework for Building Controls, in *SICE 2002 - The 41st SICE Annual Conference*, pp. 3151-3156.

GROSS, M. D., & DO, E. Y. 1999, Integrating Digital Media in Design Studio: Six Paradigms, In *Conference Proceedings of the Association of Collegiate Schools of Architecture*, Minneapolis, pp. 144-148.

HANNA, R. and BARBER, T. 2001, "An inquiry into computers in design: attitudes before-attitudes after," *Design Studies,* 22 (3), pp.255-281.

KOLAREVIC, B. 2003, *Architecture in the Digital Age: Design and Manufacturing,* Taylor and Francis, UK.

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REAL-TIME VISUALIZATION IN THE DESIGN CONTEXT

Ming Tang & Dihua Yang

Abstract

Having been a promising visualization tool since 1950s, ironically, virtual reality is not widely used in the architectural design and evaluation process due to several constrains, such as the high cost of equipments and advanced programming skills required. This paper described the collaboration between design computing courses and architecture design studios that have been taught at Savannah College of Art and Design (SCAD) in 2004 and 2005. These courses explored several practical methods to integrate Low Cost Virtual Reality Aided Design (LC-VRAD) in the architectural design process. As a summary of the collaboration, this paper refers to three main aspects: (1) How to use game engine to design an affordable VR system in the ordinary studio environment. (2) How to integrate VR, into the design process, not only as a visualization tool, but also as a design instrument. (3) How to evaluate different methods of representing architectural models based on the efficiency of workflow, rendering quality and users' feedback.

Support by the Game and Interactive Design Department at SCAD, students in the School of Building Arts implemented two Low Cost VRAD methods in various design phases, starting from site analysis, schematic design, design development to the final presentation. Two popular game engines, Epic Game's Unreal engine and Director MX's Shockwave engine, were introduced to students to visualize their project in real -time. We discussed computer-aided design theories including the application of VR, as well as digital computing and human computer interaction. At the end of each quarter, feedbacks from students and faculties were collected and analyzed. These methods were revised and improved consistently across 2004 and 2005 academic year.

Keywords: *Virtual Reality, Real-Time Visualization, Game Engine .*

INTRODUCTION: PEDAGOGICAL OBJECTIVES

As visualization and communication tools, computer renderings and fly through animations are widely used by students in the Architecture Department at Savannah College of Art and Design (SCAD). However, we find these digital tools are only used for producing the final presentation at the end of the design stage rather than being integrated into the design process at the early beginning. Many students stick with the conventional design methods by using hand drawings and physical models in the schematic design, and only use computer to generate presentation boards after the design is completed. This workflow currently widely used in the architecture design studio does not provide an efficient way to study, experience, and evaluate the design within the digital environment.

Another constrain we find in the studio is the disconnection between good-looking computer-generated (CG) renderings and the actual design quality. Although with the fast growing digital technology, CG renderings are getting more and more photorealistic, neither still-renderings nor animations can provide an interactive approach to visualize the design. The viewer's path and viewpoints are not self-chosen but pre-defined. Therefore, an important feature of spatial experiencing in the real world is missing in these visualization tools ---the interaction between viewers and the environment. Students usually spend a significant amount of time to render an animation. However, a pre-defined camera path fails to provide the freedom to interact with the design during the review. As the result, students are discouraged to spend time to create animations.

To overcome these constrains, we have explored the real-time rendering techniques and several virtual reality[1] applications, which provide students and faculties an instant 3D visualization and inter-

[1] Virtual Reality (VR) opened a new field for architecture design. The key point is the user's autonomy of movement within the virtual space (Conway Lloyd Morgan, Giuiano Zampi. 1995). With real time technology, viewers could navigate a 3D environment with external devices (joystick, mouse, keyboard or motion tracking system). The display devices such as head mount display (HMD), stereo panorama screen, and CAVE system create a fully immersive virtual environment. Also, latest web based 3D technology turned Internet into a powerful media for VR. Based on the devices and presence level, VR could be classified as "immersive VR" and "desktop VR" (John Vince. 2004).

action platform for design communication. We hope this platform could mimic the way people see and experience reality, to simulate "the viewer's ability to control his or her own actions-especially to look around and see the environment at will." (Yehuda E. Kalay. 2004). More important, we hope to find a new virtual reality aided design (VRAD[2]) method and integrate this method in the architecture design studio across all design phases.

GAME ENGINE AND LOW COST VRAD

Typical immersive VRAD systems such as HMD and motion tracking system are very expensive and require a large space to set up. They are not practical for the studio environment. Another constrain of conventional VRAD comes from its complex computer programming language. It requires designers to have advanced programming skills, and therefore restricts its application in the field of architectural design.

Compared with the high-end VR lab's equipment, we find game engine is more affordable for most general founded researchers and architecture institutes. The game industry is one of the quickest growing technology-intense industries in the last decade. The latest development of computer graphic card and the rendering technology is pushing game engines into a new level. Today, game engines are using bump map, normal map, HDRI rendering, dynamic lighting, and are capable of handling very complex, high-polygon geometries with a high frame rate. Different from the early age game model, high quality and photorealistic real-time renderings "truly blur the line between pre-rendered computer-generated film imagery and real-time rendered 3D game imagery." (Karen Moltenbrey. 2003) The most sophisticated rendering pipelines are now found not on specialized scientific machines, but on PC video cards costing less than $500. The most sophisticated and responsive interactive simulations are now found in the engines build to power games. (Michael Lewis and Jeffrey Jacobson. 2002).

Besides the low price and the ability of generating high quality renderings, another benefit of using game engine is its short learning curve. As a new generation growing up with internet and video games, most students are very familiar with the computer games and feel comfortable to navigate in the virtual environment with the keyboard and joystick. The learning curve of manipulating these game engines is very short. In 2003, we started to look for game engines and third party plug-ins capable of importing CAD models from conventional architecture design software. With the support from the Interactive and Game Design Department at SCAD, we finally selected two popular game engines. One is Epic Game's Unreal engine[3]; while the other is MacroMedia's Director MX[4] with its shockwave 3D engine. With these game engines, we designed a Low Cost Virtual Reality (LC-VR) system using a desktop, a big screen and a mouse /joystick. (Figure 1) The cost was only around $ 2,500. Compared with the expensive "immersive VR" devices such as stereoscopic display and panorama screen, this LC-VR system perfectly met our budgets.

In 2003, a joint project named "Virtual Ronchamp Church" was launched by us and the Game Design Department to test the ability of Unreal game engine. We modeled Le Corbsier's Nortdam church in CAD program and transferred it into Unreal. (Figure 2) During the ten weeks in working on this project, Unreal engine demonstrated a great power to handle complex 3D forms (such as the high-polygon curved roof), high-resolution textures (1024 pixel by 1024 pixel), and pho-

Fig 1. Devices for Desktop VR: Screen, projector, Desktop, keyboard, mouse, and joystick.

[2] VR Aided Design (VRAD), as "computer-aided design using the methods of virtual reality" (Holger Regenbrecht, Dirk Donath 1997), allows architects while being immersed into a virtual space.
[3] Epic Games' Unreal Tournament (UT) game engine is famous for its fast rendering speed, and well-designed level editing tools. UT is the most "modified" game title with over 25,000 people building their own versions of the various games in the series (Lisa Taylor, 2003). Due to its excellent rendering quality, it is even used for quick preview film scene. (http://www.machinima.org)
[4] Macromedia's Director MX is a popular multimedia-authoring tool. Compared with other web 3D tools such as Adobe Atmosphere and Active Worlds, Director MX has a larger user community and is better integrated with 3D modeling programs.

Fig 2. Screen capture from real time walk through of virtual Roncham Church in Unreal.

torealistic lighting effects. We were satisfied with the high frame rate the Unreal engine achieved with a promising rendering quality in real-time.

Meanwhile, we tested Shockwave game engine form Director MX as an alternative solution of Unreal engine. Although Director's rendering style was not as photorealistic as Unreal, it enabled us to composite text, image, video, audio, and interactive 3D model into a single interface. It also supported web publication, which would make the communication between students, faculties and clients more flexible. In 2003, an experimental project named " HomeNet Too" was developed by the author with M.I.N.D lab in Michigan Sate University. A large 3D environment was successfully published into a web format after ten weeks' development. (Figure 3)

TEACHING METHODS AND STUDENT PROJECTS

After these two experiments, we started to teach with new methods in the Architecture Department at SCAD. Two game engines were introduced to students in the spatial simulation and visualization courses in 2004 and 2005. Students were asked to bring their ongoing studio projects into these courses and use game engines to facilitate the design process.

Method 1: Unreal game engine

In this method, students from two courses worked together as a team. One course was the 3rd year Architecture Design Studio, focusing on site planning. The other course was Spatial Simulation and Visualization, which concentrated on the application of real-time rendering and visualization. Each student from Architecture Design Studio was assigned a co-worker from the Spatial Simulation and Visualization course to form a team. These two courses started simultaneously at the beginning of the quarter and worked parallel to feed each other in the subsequent ten weeks. Digital presentations supported by Unreal game engine were set up regularly and served as milestones to evaluate the design. (Figure 4)

Site Analysis and Schematic Design

To counteract the habit of using computer solely as a final presentation tool, we introduced VR environment into the early stage of the design - site analysis and schematic design. A computer-generated virtual site including accurate terrain, land-

Fig 3. Screen capture: 3D interface of HomeNetToo project

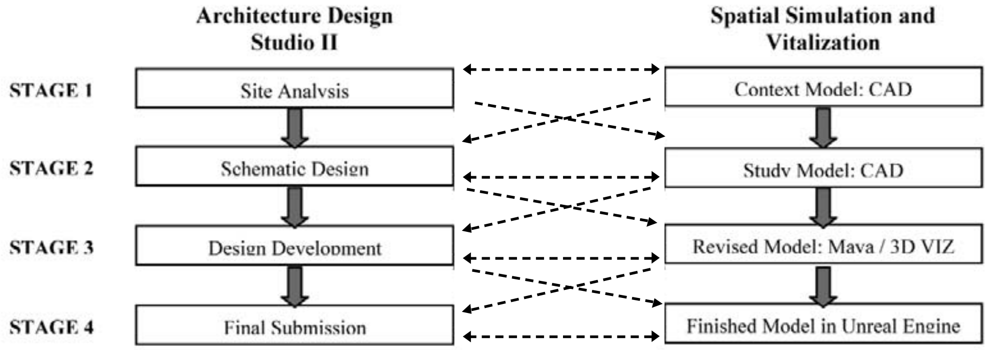

Fig 4. Diagram: interactions of studio course and electronic design course.

scape, and existing buildings, was provided to students at the beginning of the quarter. By using the game engine, environment fog, animated cloud, massive trees, and plants were carefully added to match the characteristics of the actual site. After a short period of training, students quickly grasped the technique in navigating the virtual site. Through a virtual "site tour", students dynamically experienced the environment by "walking" with their mouse and keyboard. They "stepped" on the roof of an existing building and overviewed the entire virtual site. They "flied" through the site by using "none gravity" mode and "took pictures" by capturing the snapshot and saving images for future reference. (Figure 5) By "walking through" the site, design issues related to potential building form, materials, and the relationship between new building and the existing context were discussed.

Design Development

To reduce the required programming skill and maximize the efficiency of workflow, we used Alias Maya to transfer CAD models to Unreal engine. This simple pipeline allowed students to import detailed 3D models from Micro station, Revit or AutoCAD into the real-time rendering. Textures were made in Adobe Photoshop and mapped onto the 3D geometry in Maya. Within the Unreal Level Editor, sun light and sky light were set up to generate shadow maps. Point lights and spot lights were reserved to correcting subtle lighting problems. Environment cube map was used to simulate highly reflective metal surface in real-time. In this design stage, team members from both courses were required to meet frequently to evaluate the design in the Unreal simulated environment. The following design issues were addressed among team members during the real-time walk through.

- The external circulation of the site
- The internal circulation of the building
- The visual connection between the designed building and existing context.
- The view along the proposed pedestrian path

Final Presentation

A LC-VR system was used during the final review of the 3rd year Architecture Design Studio[5]. Faculty juries sitting in front of a projected screen could observe a student operator walking inside and outside of the virtual building. The operator could also follow commands from jury members, such as "turn around", "go to the second floor", "look outside

Fig 5. Students are doing virtual site survey in Lab.

[5] The critique of 3rd year Architecture Design Studio focused on two issues. First, it was whether the design was well integrated with the existing context and connected with other parts of the site. The second issue was "the sense of a place", which shows its clear perceptual identity: be recognizable, memorable, vivid, engaging of viewers attention (Kevin Lynch, Gray Hack. 1984). Psychological and esthetics issues such as space flow, materials, proportion were also discussed during the critique.

Fig 6. Desktop VR and presentation boards were used simultaneously in the final presentation.

from the window", and etc. (Figure 6)

Some faculties actually changed their role from a passive audience to an active operator. By using the keyboard or joystick, they selected his/her own path, "walked" into the building, asked questions as well as gave comments simultaneously. It was very similar as the natural way of critiquing a building when people are physically experiencing it. From the projected screen, all viewers directly observed the operator's navigation behavior. Viewers knew which part of the lobby attracted the operator's attention, how long it took the operator to find the stairs to go upstairs, where the operator got confused and even lost his/her orientation. (Figure 7)

We did a follow-up questionnaire right after the final review. The feedbacks from colleagues, students and clients were very positive. As a conclusion, several successful aspects of this method are:

- The pipeline from CAD to real-time engine is very easy to use.
- It does not require any programming skills.
- A CAD model can be imported into VR in several minutes.
- Students do not need to spend hours to create presentation boards.

Faculties were very excited to see that LC-VR system became a new design instrument[6] to evaluate the spatial quality of a design project. Complex spatial arrangements and features of the design were recognized at the moment of "walking" inside of the building.

Method 2: Director MX's Shockwave game engine

After the success of the first method with Unreal, we started the second method in the following quarter. Macromedia's Director MX was used as an interactive presentation tool. Different from photo realistic renderings of Unreal, Director MX features abstract rendering style and rich multimedia components. Students were taught how to create a web interface to visualize their designs within an interactive 3D environment. By using Director's script library[7], various components such as text, 2D image, 3D model, flash animation, video, and audio were combined together to present a design

Fig 7. Screen capture of virtual walk through in Unreal engine.

[6] "The model becomes a design instrument, since most of the qualities of the design can be evaluated in the model." (Gerhard Schmitt.1999)
[7] Director MX's script library allows students to integrate 3D forms with various interactions and media easily. Finally, text, image, animation, 3D form, audio, and video were assembled together within a single interface.

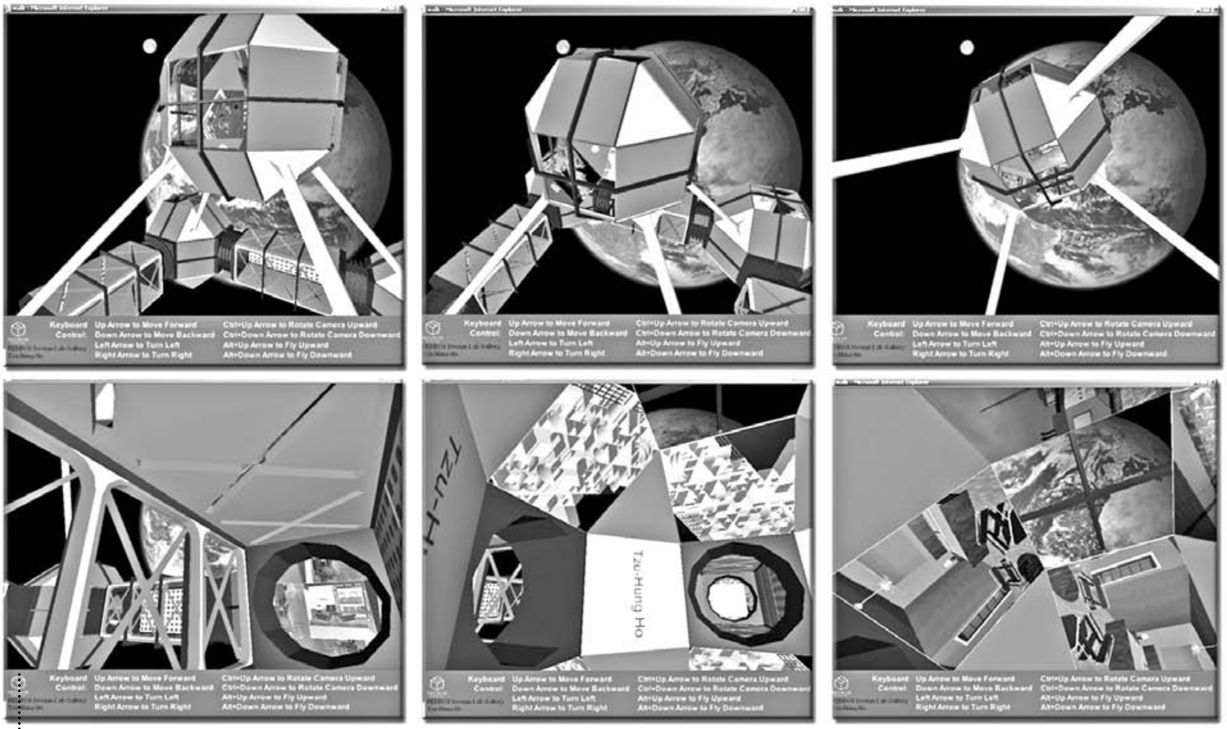

Fig 8. Animated texture as building skin in Director MX engine.

scheme on the web. To reduce the learning curve, several components[8] were developed by the author using Director's Lingo language and given to students at the beginning of the quarter.

In ten weeks, students used typical CAD modeling tools to complete their detailed models and then imported them into Director MX's engine. They published their studio projects to a 3D online environment. They designed various real-time interactions, which allowed users to walk inside of a virtual room, switch materials, rotate models and change camera angles. (Figure 8) At the end of the quarter, students uploaded their virtual environments online and collected feedback from studio advisors and other students.

Compared with Unreal, Director provides customized user interfaces and web-based presentations. It gives students a longer period of time to collect feedback from a large user group.

However, based on the survey data collected from students, the second method received a lower satisfaction rate. We believe there are two primary reasons. The first reason is the rendering quality. Unreal game engine and Director MX engine provide totally different rendering styles. VR running with Unreal can be described as "hyper reality[9]" due to its photorealistic rendering. (Figure 9) On the other hand, VR running with Director MX's shock-

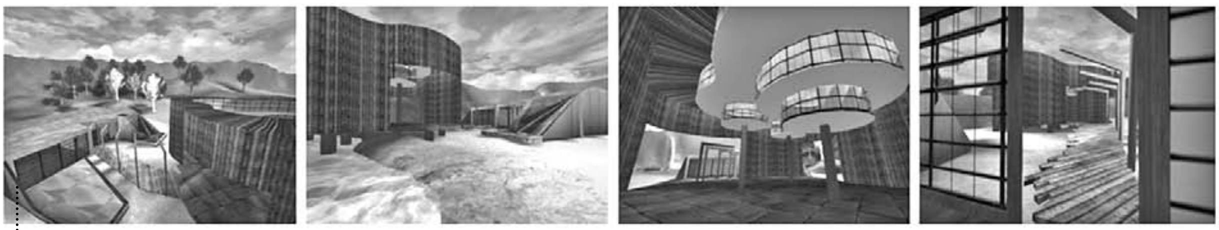

Fig 9. "Hyper reality" rendering style in Unreal engine.

[8] These script enabled students to navigate 3D world with keyboard; use bitmaps, flash movies and other video files as textures in the real time rendering.

[9] By mimicking the physical world in every detail (Yehuda E. Kalay. 2004), the advantages of "hyper reality" derive from the richness of experience, familiarity, and visual comfort they convey.

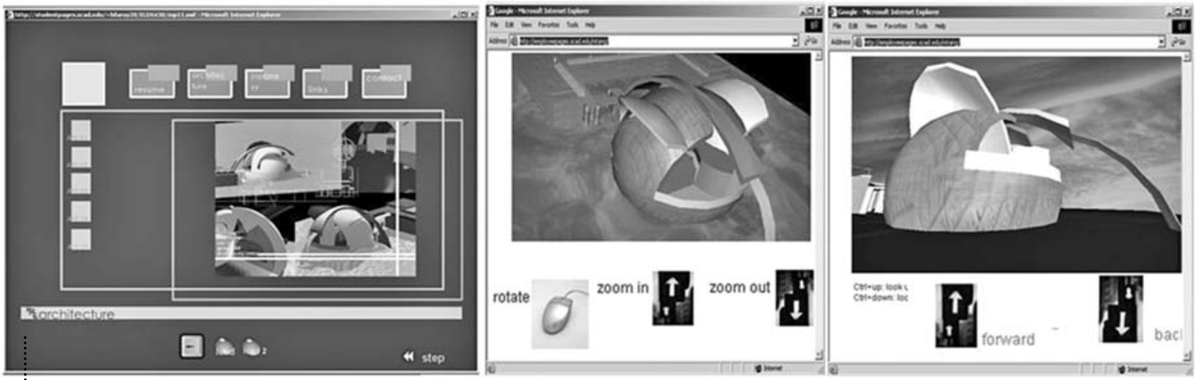

Fig 10. "Abstract reality" rendering style in Director MX.

wave engine is "abstract reality" due to its flat color and none-shadow rendering style. (Figure 10) Obviously, students preferred the photorealistic rendering than abstract rendering style.

The second reason is the interaction. Unreal engine allows viewers to interact with 3D objects in real-time. For example, users can open or close doors and windows, turn on or off lights, and even take an elevator by triggering events. (Figure 11) These interactions increase viewer's presence level psychologically and make the scene more believable. Subsequently, students feel more "involved" in the Unreal's "hyper reality" world than Director's "abstract reality" world.

Other factors affecting students' rate might be the users' presence level. Unreal's interface is a full 3D view, while Director MX is a hybrid interface with 3D windows embedded with 2D panels and buttons. (Figure 12)

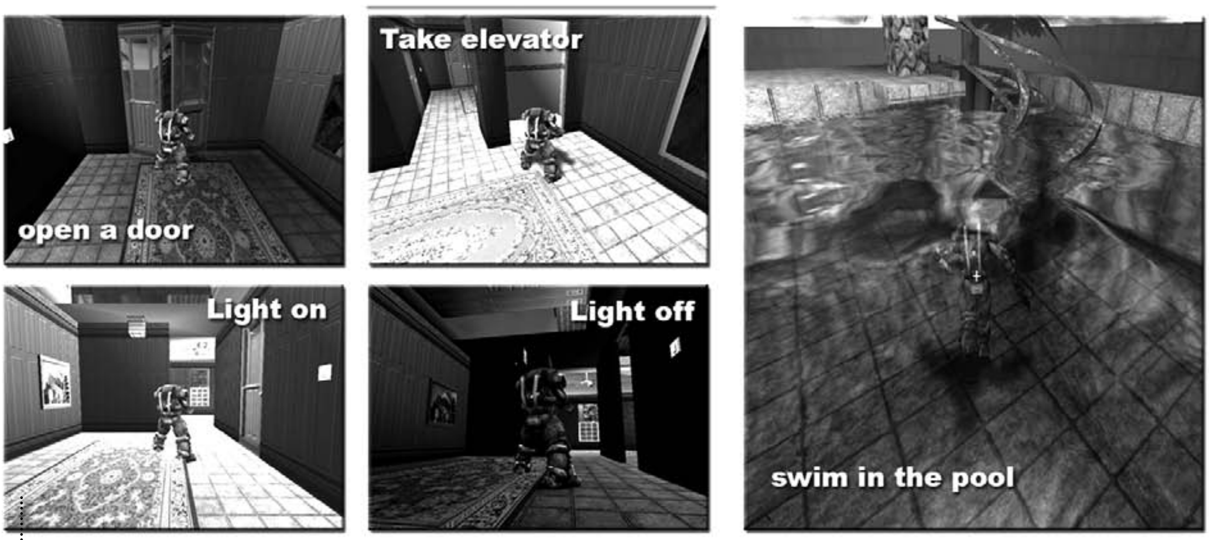

Fig 11. Real time interactions in Unreal engine.

Fig 12. Hybrid interface in Director MX.

Fig 13.
Students are doing presentations with desktop VR to |faculties and clients.

CONCLUSION

During the past three years, our work has been focused on applying LC-VR system in the early architectural design phase, where computer models confront with complex design situations. VRAD integrates site survey, design evaluation, and construction within a single digital environment, which allows a design scheme to be generated, visualized and published online quickly. In general, these two experimental methods have achieved this primary goal by introducing interactive game engines to students. The average time for a student to finish a real-time rendering project is ten weeks, including five weeks of training[10] and five weeks of working time. With a short learning curve, students can learn the real-time rendering technique fast and use it simultaneously with their design studio projects.

By implementing these two methods to the studio projects, we find some benefits as well as some constraints.

Benefit of VRAD

There is a significant amount of positive feedbacks from faculties and students in the 3rd year Architecture Design Studio. Some students commented that they learned a lot about the spatial quality when they "interactively walked inside" of the space they designed. After exploring VR environment, students had a better understanding of the meaning of "movement patterns and behavior circuits" (Kevin Lynch, Gray Hack. 1984). After observing human & environment interactions by VRAD, some students even took their projects further by independent research, which was beyond the studio's requirements. They analyzed how the color, lighting, and material could affect people's behavior in the space they designed. In the interactive environment of game engine, many design issues such as scale, proportion, rhythm, and circulation are discussed in a more "natural" way when both the professor and the student "walk" into the space simultaneously. (Figure 13) In addition, this interactive presentation has stimulated more arguments and thoughts about spatial recognition, spatial memory and other unforeseeable design issues, which are not addressed by conventional design process.

As a substitution of pre-rendered animation, which is usually the final step of a conventional design process, VRAD, as a design instrument, starts in the very early stage of the design. 3D model can be easily imported into game engine and rendered in real-time. These methods enable students and faculties to design, modify and explore the virtual space and interact with it. After each milestone evaluation in the studio, it is very easy for students to revise their design, update new models and request a second turn evaluation. (Figure 14) It becomes a cycle of refining and evaluation. It makes "design development through comments" possible (Thomas Jung, Ellen Yi-Luen Do. 2000).

Similar as a Mass Multi-player online Game (MMOG)[11], VRAD also extends the conventional studio into an unlimited digital space. It enhances the communication between faculties and students outside of the classroom. The web-based critique can flow consistently through the entire quarter among a large group of students and faculties. The equipment of VRAD, which includes a desktop, specified display and navigation devices, can also be installed in the studio environment. Compared with a web-based virtual world, the local VR system is easier to be used for some specific studio activi-

[10] There are many online tutorials available in the Unreal Website (http://udn.epicgames.com) to allow students to go start the training independelly.

[11] With the blooming of Mass Multi-player online Game (MMOG), "video game space changed from privet to public". (Alberto Iacovoni. 2004). Many online 3D worlds provide players the modeling tools they can build their own houses, decorate their own virtual rooms, and share with other players through the web.

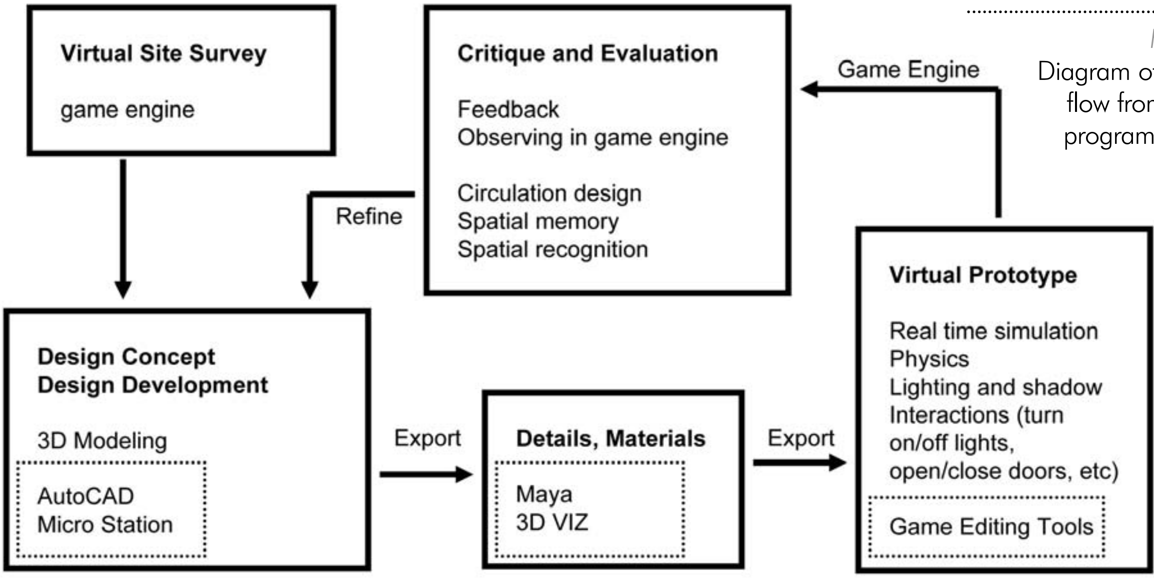

Fig 14.
Diagram of work-flow from CAD program to VR.

ties such as lectures and presentations.

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Constrains of VRAD

Although both methods have received positive feedbacks from students and faculties, there are still some technical constrains. We find the performance and frame rate of both game engines will drop down dramatically if a CAD model has a large number of geometries. This constrain requires the entire CAD model to be built up efficiently and carefully in order to minimize the polygon number as much as possible. For students, how to optimize a complex CAD model for real-time rendering is the most strategic aspect. Reducing the polygon number allows the game engine to render a CAD model with a better performance. But parallel with this benefit is a side effect that sometimes it leads to the lost of details. Low polygon model makes a complex 3D form, such as tent and dome structures, look cubical and none photo realistic.

Prospect of VRAD

Another constrain is the poor connection between CAD software and game engine. Because neither AutoCAD, Revit nor Micro Station has functions to optimize a 3D geometry or control its level of details, students have to learn Alias Maya or 3D Studio Max in order to control the polygon number. This additional step increases the learning time.

There are many other challenges and potentials of VRAD. For example, how to keep students' interest focusing on the 3D form studies instead of rendering technologies, how to embed 3D scanner and laser cut to allow projects to go across analog and digital. We will continuously conduct our investigations and experiments in the future.

By the time of writing this paper, new projects are still ongoing. Teaching methods from previous quarters have been refined constantly in the digital design courses and used as a starting point in the following quarter. Student can gain spatial experiences in an interactive digital environment. Most important, they can understand that digital model is not just for generating good-looking renderings or animations for presentation purpose, but becomes a dynamic virtual prototype which they can explore, discover, evaluate and adjust. It integrates with the cumulative sequences of knowledge in the design context and is increasingly involved into various design phases.

REFERENCES

KALAY, Y. E. , 2004, *Architecture's New Media. Principles, Theories, and Methods of Computer-Aided Design.* The MIT Press. pp.181-182

VINCE, J. 2004, *Introduction to virtual reality.* Springer, London ; New York

MOLTENBREY, K. 2003, "Character driven. --Cinematic Game or Interactive Film? The Getaway blurs the line between two genres." *Journal of the Computer Graphics World.* April. 2003

LEWIS, M. AND JACOBSON, J., 2002, "Game Engines in Scientific Research." *Communications of the ACM*. January 2002/Vol 45. No. 1

TAYLOR, L., 2003, "A mod, mod, mod, mode world---players turned programmers create the next generation of their favorite game." *Journal of the Computer Graphics World*. April. 2003

IACOVONI, A., 2004, *Game zone*. Basel : Birkhäuser ; Berlin : Springer.

REGENBRECHT H., DONATH D. 1997, "Architectural Education and Virtual Reality Aided Design (VRAD)" *Signing Digital Space, An Architect's Guide to Virtual Reality.* Daniela Bertol. 1997.

SCHMITT, G. 1999. *Information architecture, Basis and Future of CAAD*. Birkhouser.

JUNG T., YI-LUEN DO E. , 2000, "Immersive Readliner: Collaborative Design in Cyberspace." *ACADIA 2000: Elemity, Infinity and Virtuality.*

MORGAN, C.L., ZAMPI, G. , *1995, virtual architecture.* Publisher: Mcgraw-Hill.

LYNCH K., HACK G., 1984, *Site Planning.* The MIT Press. pp72.

HOON M. , KEHOE M. , 2003, "Enhancing Architectural Communication with Gaming Engines. Digital Data." *ACADIA conference paper.* 2003

APPENDIX

Appendix fig.: Screen captures from real-time in Unreal engine. 56 frames per second

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VISUALIZATION FOR CITIZEN INITIATED PUBLIC PARTICIPATION: A Case Study

Mark Lindquist

Abstract

This paper examines the impact of a citizen initiated public participation process on preparers and presenters of digital visualizations for spatial design decision making. Visualization for public participation enables communication between professionals and laypeople to occur with far greater success than through conventional methods. Further, visualization utilizing real-time immersive technology allows for far more effective communication of the spatial impact of design proposals than conventional media offer, facilitating negotiation and interaction with space by providing the means to virtually walk around a digital model. In addition, the effectiveness of real-time immersive visualization in bridging the public-professional communication gap can empower the public, offering the opportunity to confront professionals and to force engagement in a process of public participation on the public's terms.

Through discussion of a case study from the University of Toronto's Centre for Landscape Research (CLR), this paper examines the impact on the visualization process when the public are able to invert the conventional model of public participation by initiating the dialogue with professionals. This paper argues that a citizen initiated public participation process increases the necessity for a sound methodology and code of ethics of visualization for public participation. When the public are able to utilize technology to invert the conventional public-professional role, issues of validity, reliability and ethics are placed at the forefront of the discussion greatly increasing the scrutiny placed on both the technology and those preparing and presenting the visualization.

Keywords: *Visualization; Ethics; Computer Graphics; Simulation Validity; Decision Support.*

INTRODUCTION

Public participation allows for democratic input on decisions made by a few people that affect many people. In the spatial planning disciplines, the public participation process frequently involves professionals communicating complex spatial arrangements to laypeople. However, traditional methods of spatial representation, orthographic plans and sections, are difficult for the layperson to decipher. The failure of traditional planning visualization, such as static two dimensional representations, for communicating to the public has been presented, and the advantages of additional visualization techniques in a conventional public participation model have been evaluated by Al Kodmany (1999). Lange (2005: 5) has offered that many of the problems contributing to unsuccessful public participation processes are caused by a communication breakdown between the public and professionals, which visualization can aid in overcoming.

It has been demonstrated that real-time visualization offers a highly effective means to engage the public in spatial decision making. (Bishop, 2005; Kwartler, 2005). However, it has been asserted that if computer based visualization is at all utilized in the design process, it is primarily used as a sales tool, employing static glossy images or, at best, video based cinematic animations that are aimed at selling a proposal to the public rather than encouraging them to make a critical decision (Danahy, 2004: 161). It has been presented that when professionals are reluctant to engage with a willing public in a process of consultation, the public are able to force engagement with professionals via the use of the real-time visualization, inverting the conventional process by convincingly presenting their visual understanding of a design proposal (Lindquist and Danahy, 2006). When visualizations are relied upon for real-world decision making, validity, reliability and ethics in the preparation and presentation of visualizations are a significant issue. These issues have been discussed and an interim code of ethics offered for preparers and presenters of visualizations in a conventional process, where the developer or government body control and edit

the information that is available to the public for input (Sheppard, 2001; Sheppard, 2005).

This paper presents an unconventional process of dialogue where the public were the main proponents of opening communication with design and planning professionals, and evaluates the impact on the visualization process. Via a case study of a publicly initiated participation process, in which Centre for Landscape Research (CLR) members were involved, the discussion will be expanded by examining the opportunity for publicly initiated engagement with planners and designers, and how that process impacts preparers and presenters of visualizations. This paper will be presented in two parts; the first will present a case study of a publicly initiated participation process, the second will discuss methods and techniques to address bias for preparers and presenters of visualizations in a publicly initiated dialogue.

PART 1 - PUBLICLY INITIATED DIALOGUE

Public participation can be broadly defined as 'forums for exchange that are organized for the purposes of facilitating communication between government, citizens, stakeholders and interest groups, and businesses regarding a specific decision or problem' (Renn, Webler et al., 1995: 2). Arnstein identified the degree of inclusiveness of various models for public participation that range from manipulative non-participatory models to scenarios where citizens are empowered and in control of the process (Arnstein, 1969). Arnstein asserts that, at that time, in many formalized public consultation arenas the models seldom surpassed the 4th rung of the ladder, 'token placation' (Arnstein, 1969: 217). In extreme instances the author has experienced professionals who ignore public requests to open a dialogue in relation to a contentious project. In such cases, the public are forced to confront the professionals in an attempt to engage in a dialogue, which is no small task; historically the public have lacked the professional's ability to read conventional spatial representations, as well as, the image making skills to represent alternative proposals, which design professionals are able to use to their advantage. This disparity in both the reading and creation of spatial information has enabled professionals to argue their point far more effectively than the public. Further, when challenged, professionals have historically controlled information and hence are far better equipped to dispute a challenge to the design proposal than are those lacking site specific information.

The Fort York Case Study

In the process of development of a condominium project for the Toronto waterfront the CLR was approached by the Friends of Fort York (The Friends) when City officials and the project developer ignored The Friends' request to be have their opinions heard in relation to the project. A local community group, The Friends has a long standing commitment to stewardship of the interests of the Fort in both its planning and on-going programming of interpretive events and improvement. The Friends asked the CLR to visualize the proposal so they could better understand the ramifications of the condominium and scrutinize it in the CLR immersive lab (Figure 1).

Following sessions in the lab with CLR members it was decided by The Friends that they would invite city officials and the developer to discuss the developer's proposal in relation to the existing masterplan for the area which prior city officials and The Friends had agreed on as a positive proposal a decade earlier. Owing to The Friends' vested interest in the proposal, it was viewed that the CLR could

Fig 1. Community meeting facilitated in the Centre for Landscape Research (CLR) Immersive Visualization Lab.

Fig 2. Aerial view of the real-time digital model of the Fort York urban design proposal.

provide neutral facilitators, as well as, the technology necessary, to develop the visualization and facilitate a meeting. The CLR agreed to participate and developed a real-time digital model of the proposal for examination in the immersive lab (Figure 2).

The Friends invited the developer, the developer's architect, and city officials to a series of workshops aimed at achieving better built form which would greatly impact on both the ground level experience in the new community as well as the experience from within Fort York (Figure 3, 4). The developer and City of Toronto were reluctant to alter any built form as they had fast tracked the proposal through the planning process. This resulted in a stalemate and the case went to the Ontario Municipal Board (OMB), a Provincially appointed adjudicative tribunal that hears appeals on planning applications and resolves land use disputes (Omb, 2005). The community group was permitted to present their visualizations, albeit in two-dimensional printed screen captures of the real-time model (Figure 5, 6). Though static and two-dimensional, rather than real-time immersive, the imagery was threatening enough to the developer that the accuracy of the model was challenged, which withstood the board's scrutiny. However, the community group was unable to convince the board of the value of the ground level experience, and as a result the preferred bottom line of the developer was ruled as paramount, and no concessions to improve the ground-level experience of people within the Fort or the proposed neighborhood were made.

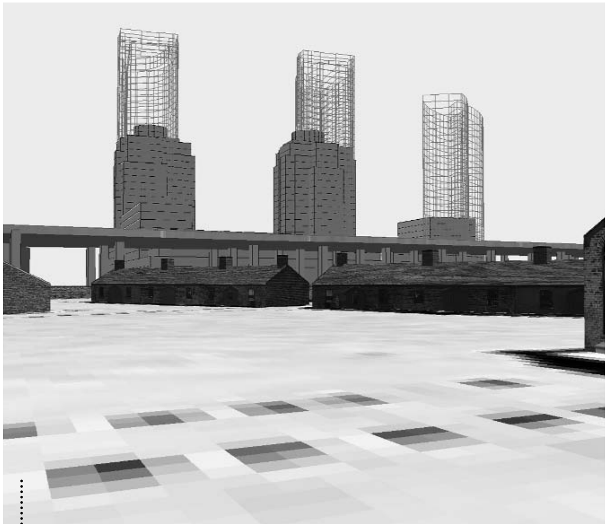

Fig 4. Ground level analysis within Fort York. The City of Toronto Official Part 2 Plan is shown (solid) with the proposed developer high-rise juxtaposed in wireframe.

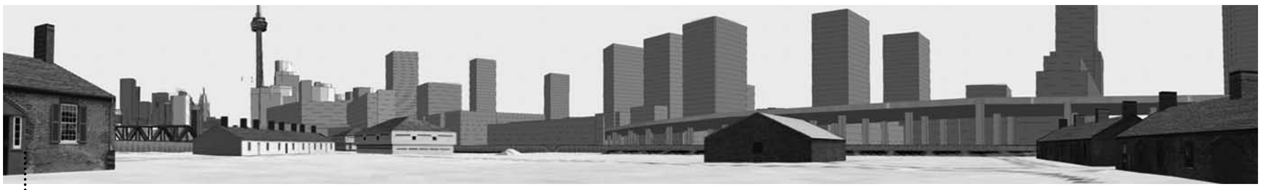

Fig 3. Panorama of the impact of proposed development on the ground level experience within Fort York.

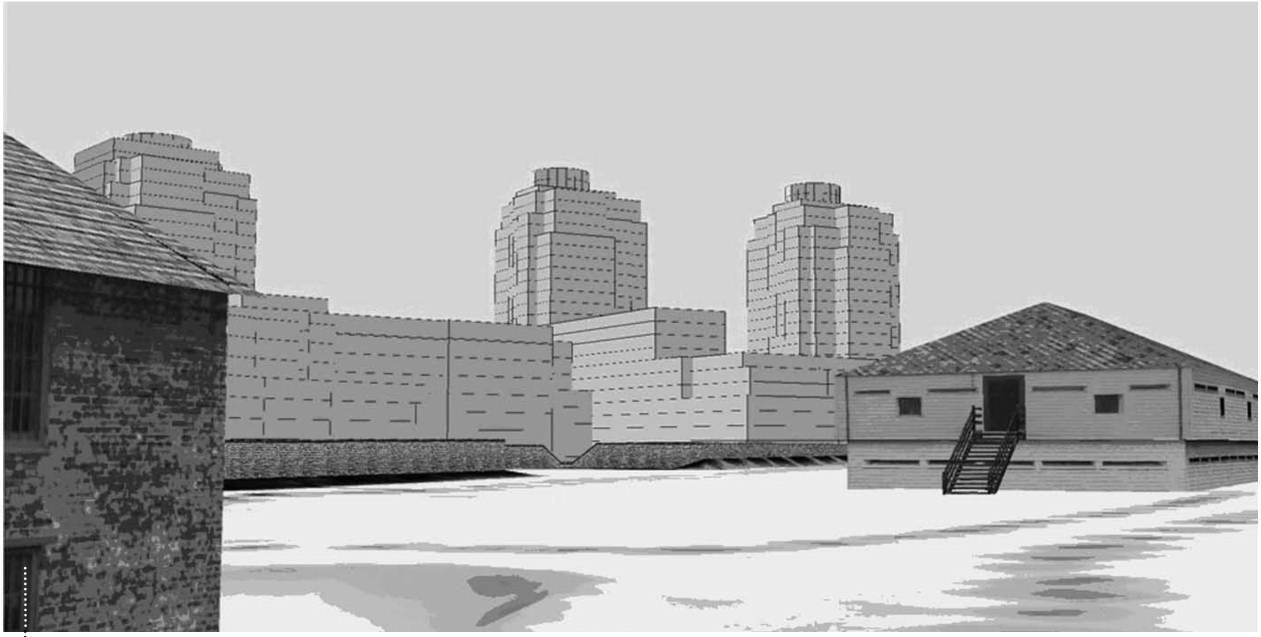

Fig 5 & 6. Ground level analysis, two-dimensional printed screen captures of the real-time model that were submitted for the OMB hearing

PART 2 - BIAS IN PUBLICLY INITIATED DIALOGUE

In this case The Friends clearly demonstrated a bias that would need to be addressed in the process of facilitating meetings. As well, the confrontational nature of the process lends itself to bias on the developer's side. The preparers and presenters of the visualization would be scrutinized by the professionals even more so than normal, as they were viewed by the developer as being hired by the community group and not acting as neutral parties. Arguably this placed even more pressure than normal on the visualization team to provide valid, reliable visualizations. The polarized nature at the beginning of the process was quite different from a standard invited process driven by city officials in that the parties of the developer and city were on the same side in denying the public's request for dialogue to occur. Human bias was inherent to the dialogue and it was acknowledged by CLR members that it would need to be addressed via the visualization.

Human Bias

In a conventional public participation process, initiated by professionals, there is an assumption of an open-ended and unbiased discussion in order to arrive at consensus. In a publicly initiated process bias is essential; initiating a dialogue with developers and city officials necessitates a particular point of view on a topic that has not been addressed and is in contrast to the 'party line'. Such polarized bias does not need to exist for a conventional top down public participation model to occur, though it very well may exist or develop; a developer ignoring the public's request to be heard could cause the public to solidify their opposition, resulting in the developer denying further public involvement. Overcoming bias in such polarized groups increases the pressure on the visualization to convey as neutral as possible a representation.

Visualization Bias

In a conventional process of visualization for public participation ethical issues center on ensuring what is being presented is portraying an accurate and reliable depiction in order to garner consistent feedback from the public. In a publicly initiated process accuracy is vital, but less important for garnering consistency of opinion. As observed in the case study, accuracy was vital so that the city officials and the developer could not refute the model and hence derail the process they were hoping to avoid in the first place. In addition to human bias there is potential bias in the act of preparing a visualization that can be intentional and unintentional, attributed to: inadequate data, modes of presentation, context of production and perceptual variability between preparers of visualizations (Sheppard, 2001:187-189). This section will present the methods and techniques employed in preparing and presenting the visualization in the case study.

Constraints on Visualization Bias

Four constraints on bias in visualization have been identified; system constraints, policy constraints, professional guidance & training, and monitoring & enforcement (Sheppard, 2001: 189-192). In the Fort York case the unique circumstance of publicly initiated dialogue meant no policy for such a case existed. In addition, policy for the use of digital visualization for communicating to the public was also non-existent, which meant no monitoring or enforcement could be carried due to the lack of comparative knowledge of the process. Indeed it has been presented that, in general, frameworks seldom exist for visualization in a public participation process (Sheppard, 2001: 191). Only system and professional constraints on bias were present in this case to temper the potential bias during the preparation and presentation of visualization. Members of the CLR, the preparers and presenters of the visualization in this case, were dependant upon the technology and professional knowledge to create a reliable, accurate and valid visualization.

Addressing Bias in Publicly Initiated Dialogue

The use of specialist software and hardware at the CLR made for a difficult task of convincing the developers of validity. Past visualization work conducted by the CLR was used as precedent to convince the city and developers of the pedigree and validity of the process. The lack of policy constraints placed the onus on the CLR to regulate its own visualizations without an outlined timeframe or overall framework known throughout the project. Lacking a framework CLR members could not know the extent to which the process would evolve. As a result, much time was spent ensuring accuracy at the outset of the project Ultimately the CLR relied on past models of best practice to use as precedent to convince city officials that the model was created without bias. The following section outlines the methods employed to address bias in the process of developing the visualization.

Context of Production

No existing framework for a publicly initiated process existed in Toronto, therefore objectivity was paramount. While CLR members had opinions it was necessary to present information as neutrally as possible. The process involved developing a contextual model to site the developers' proposal, creating an accurate model of that building, and developing alternatives using the model to compare options. The apparatus used in the CLR Immersive Visualization lab for developing the model and facilitating the sessions included com-

mercially available and research produced software that ran on commercial and specialist hardware. The majority of the digital modeling was completed on a standard desktop PC using a combination of Autodesk AutoCAD 2000 and Autodesk 3D VIZ (Autodesk, 2000; Autodesk, 2000). The two Autodesk products were used as they offered the highest level of compatibility at that time with city of Toronto data and were the most familiar modeling environment for CLR members, contributing to the overall accuracy of the models and confidence in the mode of production. PolyTRIM, software developed by the CLR, was used for real-time modeling and presenting during meeting sessions running on a Silicon Graphics Onyx II workstation connected to 3 data projectors for 180 degree immersion (Danahy and Hoinkes, 1995). PolyTRIM has been developed with expressed purpose of real-time modeling and immersive viewing of landscape, and allows for a highly realistic representation visualization environment (Lange, Hehl-Lange et al., 2004: 188). For the Fort York project PolyTRIM became the de facto environment for assembling disparate components from various data sources for modeling and viewing in real time, a method of working that was unavailable in commercially available software at that time. This enabled transferred models from the developer to be assimilated into the context model. This was necessary due to city officials mandating further in the process that the developer must supply data to ensure accurate visualization, which contributed to alleviating bias as the developer's architect was supplying the model, removing the onus for accuracy from CLR members.

Perceptual Variation Between Preparers of Visualizations

CLR has a long history of developing digital models for urban design, planning and landscape architecture proposals, including models of Ottawa, Stanley Park in Toronto and a highly detailed model of the University of Toronto downtown campus (Danahy, 1987; Danahy, 1999). The potential perceptual variation between those preparing the visualization was addressed by using previous models developed in the above referenced scenarios as a point of comparison to work towards. In addition, the team was composed of only two CLR members, while the modeling of the contextual information in the Fort York case was completed by one CLR member.

Inadequate Data

The Fort York project owes much to the historical development of a base City of Toronto model that has evolved over the past decade. Without the model available the work involved to create the context would not been complete in time for The Friends to initiate dialogue with the professionals. The establishment of a base model is critical to the process of participation. The base model included a Digital Terrain Model (DTM), a combination of orthophoto and masterplan drawing for contextual terrain and, context buildings and city infrastructure such as the Gardiner expressway. Following will be a discussion of the data types and methods for addressing bias as per each typology.

Inadequate Data - Terrain

In this instance the CLR possessed a very detailed Digital Terrain Model (DTM) for the site, constructed from 10cm spot elevations acquired from a specially commissioned laser flyover of the Fort York site for a previous project. In addition a relatively detailed DTM for the context terrain was created from 5 metre contours data that was stitched together with the site terrain. The highly accurate geo-referenced DTM was used in conjunction with geo-referenced orthographic photography as the point of reference for the modeling environment. The DTM was triangulated using highly detailed 10cm spot elevations from a laser flyover, creating very accurate terrain for the area of study. While visually accurate this resulted in an extremely large DTM file that reduced performance of the model and impacted the real-time qualities of viewing. For the sake of the real-time sessions the model was simplified using an algorithm from 3D Studio Viz to reduce the polygon count. Alternatives were created by CLR members comparing each version with the original for similarity and evaluating tradeoffs in performance. The experience of senior CLR researchers was relied upon to decide on an appropriate level of abstraction.

Inadequate Data - Existing Built Form
Highly detailed photo-realistic buildings were created to enhance ground-level views from within the Fort. Buildings in the immediate context that were deemed to have impact on important views were textured with photographs. As detailed plans and sections were not available the scale as supplied in the City of Toronto model was used as the base and textured upon. Each building, in the Fort or immediate vicinity, was checked with its real-world equivalent for accuracy by comparing photos and proportions and counting known elements for distances. Massing block models were supplied for the greater context buildings by the City of Toronto. Buildings within Fort York were individually modeled from historic plans and sections supplied by The Friends of Fort York. These were textured with images taken of the buildings on site. The major site feature, the Gardiner Expressway, was modeled in detail with texture applied. Existing context buildings were supplied by the City of Toronto from their own 3d urban design model and aligned with the high accuracy to the DTM base geo-referenced. The supplied buildings did not take into account terrain and as a result were at an elevation of 0. To accurately place the buildings in the z coordinate the elevations of the rooftops were used to raise the buildings to the real-world elevation.

Inadequate Data - Proposed Built Form
City officials were able to convince developers to supply their CAD models for inclusion in the model developed by the CLR. This suppressed issues of bias in CLR modeling raised by the developer. Main concerns were scale and location, as typical architectural CAD models are seldom geo-referenced and typically do not use the same scale as GIS and landscape planning models. The phase of the project resulted in the developer supplied models being not highly detailed. As a result, scaling the model to the correct units and locating it in space based on the site plan for x and y and DTM for z elevation was deemed satisfactory by the developer.

Modes of presentation
The use of real-time immersive visualization contributed greatly to controlling bias in the viewing of and interaction with the model. The challenge with real-time visualization is that there is no fixed point of view to develop as there is in a still image or animation; the model must be reasonably detailed from all vantage points if the representation is to be trusted. A large amount of work was devoted to the contextual areas around the Fort. This resulted in virtually any vantage point that could be requested to be shown, resulting in no discussion of bias in the viewpoints to be raised by any parties.

DISCUSSION

The unique circumstance of publicly initiated dialogue meant no policy for such a case existed which meant no monitoring or enforcement could be foreseen. In the Fort York case study the lack of professionals using the technology invited the public to confront the professionals utilizing the technology themselves. The developer and their designers were not technologically equipped to argue effectively against the real-time technology employed by The Friends, as prepared by the CLR, which shifted power from the professionals to the public. In the end, The Friends' interjection into the process was too late to impact the individual project. However, from the point of view of the city officials, the technology was robust, or challenging, enough to necessitate integrating the detailed modeling into their planning process for adjacent sites, whenever the public requested it.

With the proliferation of representation and visualization technology coupled with an increased knowledge to use these tools, the average consumer is far more capable of both understanding and creating spatial representations than they have been in the past. While the day is not yet upon us that the public are able to completely construct their own urban design and planning models, this is not far off with the current wide spread use of gaming level building software by untrained individuals to create realistic virtual worlds for play. As the tools become ubiquitous via the internet and the process of creation simplified through advances in interactive design the public are fast approaching the image making skills of professionally trained designers.

The search engine company Google, who recently acquired SketchUp, are offering a free version of the software for download and encourage the public to model their own houses and environments, as well as, to post these models on to the web (Google 2005). Students of Landscape Architecture at Victoria University of Wellington, and North Dakota State University, have experimented with this technology for larger scale interventions in the landscape, albeit with little success owing to the scale of the digital model required for landscape evaluation.

While still in its infancy the technology points to the increasing capacity in the average consumers spatial literacy and knowledge of tools as a growing trend. An established code of conduct for visualization is necessary to protect the public from the onslaught of representations that may proliferate. Accurately adhering to, and developing, a code of conduct to prepare valid, reliable and unbiased visualizations will allow design professionals to distinguish themselves from the layperson. Offering an expertise that will be out of the depth for the DIY or at home visualization preparer will enable the designer to distinguish their skills, which at this point in time arguable are no more valid, or reliable, than the at home hobbyists.

Promising research is being carried out at CLR investigating methods and techniques of interactive design collaboration over the internet to overcome the geographical constraints from visualization preparation and presentation. This will aid the process as experts will soon be able to collaborate with real-time models and share their expertise, offering the opportunity to increase the validity and reliability of models and processes. In addition, this will place those involved at the centre of any debate, increasing their accountability, adding additional scrutiny and questioning their bias, when compared to a geographically constrained process.

CONCLUSION

In the Fort York case the public successfully initiated a dialogue and forced their issues to be heard, increasing their empowerment in relation to Arnstein's ladder, and surpassing a conventional process where their view could have been ignored. While unsuccessful in changing the process of development for the specific condominium, The Friends were successful in altering the planning and development process for adjacent sites. Without the aid of real-time visualization, and those able to prepare and present using such technology, the community group would not have been able to bring uninterested officials and developers to the table. Owing to the high stakes involved in many public participation processes, those preparing visualizations must ensure they are accurate and valid, or risk the work and issues identified being deemed invalid, negating any progress gained. A publicly initiated dialogue further increases the scrutiny on those preparing and presenting the visualization, and necessitates accurate, reliable and valid models and methods to contribute to the decision making process.

REFERENCES

AL-KODMANY, K. 1999, "Using visualization techniques for enhancing public participation in planning and design: process, implementation, and evaluation", *Landscape and Urban Planning,* 45(1), pp.37-45.

ARNSTEIN, S. R. 1969, "A Ladder of Citizen Participation", *JAIP,* 35(4), pp.216 - 224.

AUTODESK. 2000, "AutoCAD 2000", www.autodesk.com/autocad,

AUTODESK. 2000, "Autodesk VIZ 4.0", www.autodesk.com/viz,

BISHOP, I. D., 2005, "Visualization for participation: the advantages of real-time?" *Trends in Real-Time Landscape Visualization and Participation,* Anhalt University of Applied Sciences, Dessau, Germany, Herbert Wichmann Verlag, pp.2 - 15.

DANAHY, J. W., 1987, "The Parliamentary Precinct Study: Visual Simulation in Urban Design Decision Making", *American Society of Photogrammetry Proceedings of GIS-87,* San Francisco

DANAHY, J. W., 1999, "Visualization Data Needs in Urban Environmental Planning and Design", *Photogrammetric Week 1999,* FRITSCH/SPILLER, Wichmann, Stuttgart

DANAHY, J. W., 2004, "Dynamic Immersive Visualization: Negotiating Landscape Images", *The Real and Virtual Worlds of Spatial Planning,* M. KOLL-SCHRETZENMAYR, M. KEINER and G. NUSSBAUMER, Springer, Berlin; New York;

DANAHY, J. W. and R. HOINKES, 1995, "PolyTRIM: Collaborative Setting for Environmental Design", *CAAD Futures '95, The Global Design Studio*, Singapore,

GOOGLE. 2005, "Google SketchUp", http://sketchup.google.com/,

KWARTLER, M., 2005, "Visualization in Support of Public Participation", *Visualization in Landscape and Environmental Planning: Technology and applications*, I. D. BISHOP and E. LANGE, Taylor & Francis, London

LANGE, E., 2005, "Issues and Questions for Research in Communicating with the Public through Visualizations", *Trends in Real-Time Landscape Visualization and Participation,* Anhalt University of Applied Sciences, Dessau, Germany, Herbert Wichmann Verlag

LANGE, E., S. HEHL-LANGE, et al., 2004, "Assessment of Urban Green Space Qualities Using 3D Visualization Tools", *The Real and Virtual Worlds of Spatial Planning,* M. KOLL-SCHRETZENMAYR, M. KEINER and G. NUSSBAUMER, Springer, Berlin; New York;

LINDQUIST, M. and J. W. DANAHY, 2006, "Community Initiated Public Participation: Altering the Urban Design Decision Making Process with Real-Time Immersive Visualization ", *Corp2006 & Geomultimedia06: Proceedings at Technical University of Vienna,* Vienna, Austria

OMB, 2005, "Ontario Municipal Board", Retrieved November, 2005, from http://www.omb.gov.on.ca/

RENN, O., T. WEBLER, et al., 1995, "A Need for Discourse on Citizen Participation", *Fairness and Competence in Citizen Participation: Evaluating Models for Environmental Discourse,* O. RENN, T. WEBLER and P. WIEDEMANN, Kluwer, Dordrecht, The Netherlands

SHEPPARD, S. R. J. 2001, "Guidance for crystal ball gazers: developing a code of ethics for landscape visualization", *Landscape and Urban Planning,* 54(1), pp.183-199.

SHEPPARD, S. R. J., 2005, "Validity, reliability, and ethics in visualization", *Visualization in Landscape and Environmental Planning: Technology and applications,* I. D. BISHOP and E. LANGE, Taylor & Francis, London

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DESIGN EXPLORATION USING A SHAPE GRAMMAR WITH A GENETIC ALGORITHM

Orestes Chouchoulas & Alan Day

Abstract

Although the idea of linking a shape grammar to a genetic algorithm is not new, this paper proposes a novel way of combining these two elements in order to provide a tool that can be used for design exploration. Using a shape grammar for design generation provides a way of creating a range of potential solutions to a design problem which fit with the designer's stylistic agenda. A genetic algorithm can then be used to take these designs and develop them into a much richer set of solutions which can still be recognised as part of the same family. By setting quantifiable targets for design performance, the genetic algorithm can evolve new designs which exhibit the best features of previous generations. The designer is then presented with a wide range of high scoring solutions and can choose which of these to take forward and develop in the conventional manner. The novelty of the proposed approach is in the use of a shape code, which describes the steps that the shape grammar has taken to create each design. The genetic algorithm works on this shape code by applying crossover and mutation in order to create a range of designs that can be tested. The fittest are then selected in order to provide the genetic material for the next generation. A prototype version of such a program, called Shape Evolution, has been developed. In order to test Shape Evolution it has been used to design a range of apartment buildings which are required to meet certain performance criteria.

Keywords: Shape Grammar, Evolutionary Design, Genetic Algorithm, Design Exploration

INTRODUCTION

Evolutionary systems, and particularly those using genetic algorithms at their core, are very powerful and versatile. They enable the designer to consider any number of criteria simultaneously without the need to define a priori solutions and provide the means for optimising designs through an extensive examination of alternatives. However, if these tools are to infiltrate architectural design studios they need to be generic. They also need to produce designs that are meaningful to their designers and pertinent to each specific design problem. The key to providing these features seems to lie with the choice of representational system for the designs, as well as the way in which each design is described when using a genetic algorithm (Woodbury, 1993). Shape Evolution addresses this by using a shape grammar to generate the initial designs and then transfers the outputs to a genetic algorithm for design development. The novelty of the approach is in the way in which the linkage between the shape grammar and the genetic algorithm takes place.

SHAPE GRAMMARS

A shape grammar consists of a vocabulary of shapes, a set of shape rules, and an initial shape. The rules result in the transformation of a shape, or collection of shapes, to a new shape. Applied recursively on the initial shape, the rules produce designs that are said to belong to a language (Stiny and Gips, 1972; Stiny, 1975).

Shape grammars have, since their inception, been used for both analysis and synthesis. In terms of analysis, they have been called to serve as descriptors of style and have been successful when applied analytically to the definition of historical styles including Palladian villas (Stiny & Mitchell, 1978), Wren's City churches (Buelinckx, 1993), Frank Lloyd Wright Prairie houses (Koning & Eizenberg, 1981), window designs (ROLLO, 1995), Japanese tearooms (Knight, 1981), Mughul gardens (Stiny & Mitchell, 1980) and Hepplewhite chairs (Knight, 1994).

Another stated aim of the shape grammar formalism is to provide a mechanism for the creation of new design languages. This is achieved by creating a vocabulary and a set of rules from scratch.

The use of shape grammars in a generative, rather than an analytical capacity is of particular interest as a very simple grammar with a limited vocabulary and a few rules can create significantly complex and unanticipated results.

GENETIC ALGORITHMS

Genetic algorithms were developed in the 1970s by John Holland (Holland, 1975) in an effort to formally understand biological adaptation in nature. Much like the organisms they were meant to study, genetic algorithms have taken on a life of their own and have proven robust in tackling optimisation problems and exploring very large search spaces (Goldberg, 1989). This makes them appropriate to the solution of design problems when these are represented as a search through a design space where each point in the space is a potential design. The main strength of genetic algorithms as problem solvers is that they do not require an explicit optimal solution generation method, relying instead on a generate-and-test procedure.

COMBINATION OF GENERATION AND EVOLUTION

Shape grammars are good at providing an aesthetic and organisational specification for the generation of forms. Genetic algorithms are robust search algorithms that can be used very effectively for finding solutions that satisfy a set of defined conditions, such as the quantitative requirements of an architectural design. Combining the two produces a system where the design space is specified using a shape grammar, which is then explored using a genetic algorithm.

The combination of a shape grammar with a genetic algorithm has been proposed by others, including Gero & Kazakov (1996), Rosenman & Gero (1999) and Loomis (undated). Also, Shea's work on shape annealing (Shea & Cagan, 1997) is an example of a similar approach which optimises structural design and produces unconventional but highly functional solutions. The novelty in the current approach lies in way in which the shape grammar is linked to the genetic algorithm, through the use of a shape code.

SHAPE CODE

In Shape Evolution, the generation process involves a chain of shape grammar rule applications starting with an initial shape. The shape grammar is defined with a small number of shapes in the vocabulary along with a small number of rules. Consequently, it is relatively easy to represent the generation process for a design as a simple string. This describes the sequence in which the shape grammar rules were applied. This string, called a shape code, has been employed by Koutamanis (2000) for the purpose of cataloguing and retrieving designs.

Using the shape code as the genotype (the building blocks that are used by the genetic algorithm) offers three very significant benefits. Firstly, it ensures that all the designs created during the evolutionary process are valid in the language. It also means that the genetic algorithm's operations on the genotype, such as crossover and mutation, alter the selection and sequence of shape grammar rules used for the generation of a design, which are potentially very meaningful alterations. In addition, the process of converting the shape code into a three-dimensional form is simply a matter of applying the shape code sequence to the shape grammar, thus producing geometry. The designs can then be evaluated with respect to their physical attributes.

INVALID SHAPE CODES

Using the shape code as the genotype introduces a complication. The spatial overlapping of abstract shapes is usually not a problem, but when these shapes represent physical entities, as happens when a shape grammar is used to generate buildings, clashes can easily result. Invalid shape codes need to be weeded out before they ever make it to the evaluation algorithms. Provided that the initial population fed into the genetic algorithm is comprised entirely of valid individuals, it is only at crossover

and mutation that invalid shape codes can be produced. A checking stage is therefore required at each instance of crossover or mutation. This ensures that new elements are only added to areas that were previously empty.

SYSTEM OVERVIEW

Shape Evolution is a prototype system combining shape grammars and genetic algorithms in the way described, implemented as a computer program. It receives input from the designer and outputs concept design solutions that satisfy a set of requirements and form part of the designer's language of design. Figure 1 shows a general flowchart of the system.

The program starts by receiving user input, which includes a definition of the shape grammar to be used, as well as goal values for quantifiable properties of the design. The genetic algorithm will be using these to assign a score to each design according to how close it is to the goal values. Further user input includes genetic algorithm variables such as population size, mutation rate, and the end condition, which determines when Shape Evolution will terminate its run. This can be satisfied either after a certain number of generations or when designs with scores better than a user-defined threshold value are produced.

Shape Evolution then proceeds to generate the initial population using the shape grammar. Every design in the population is then evaluated and has a score attached to it. The fittest (highest-scoring) members of the population are then selected. These provide the genetic material from which the next generation is produced. The genotypes of the selected parents are paired up randomly and crossover is employed to generate two new genotypes per mating.

After being mutated probabilistically, these genotypes form the new generation of designs. A further evaluation and scoring of the new population helps determine whether the end conditions have been met. If not, the selection-crossover-mutation cycle starts again and a new population is generated. If the end conditions are satisfied the best designs produced are presented to the designer and Shape Evolution stops. What happens next is up to the designer. Some of the ultimate designs might be usable as they are, others might serve as inspiration, and others may be entirely useless.

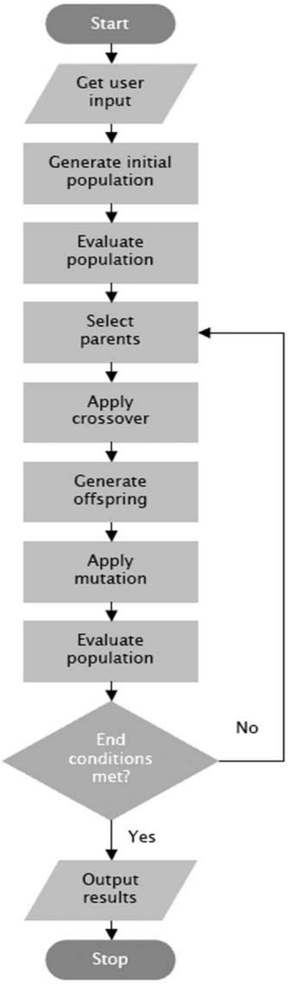

Fig 1. Shape Evolution flowchart

THE APARTMENT BLOCK PROBLEM

In order to test the system a simple problem which seeks innovative yet functional design concepts for a multi-storey apartment block has been investigated. For the sake of simplicity, the proposed building consists of a series of similar apartments along with the horizontal and vertical circulation spaces connecting them. A necessary requirement is that all circulation is contiguous and that there is an accessible entrance on the ground floor.

A simple shape grammar producing designs of this sort can be constructed with only two shapes in its vocabulary: a multi-purpose circulation unit and the apartment unit itself. The circulation unit can be

approximated by a 4m x 4m x 4m cube, an envelope that can easily accommodate both vertical and horizontal circulation, as seen in Figure 2.

The apartment unit is a generously sized single bedroom apartment at 16m x 4m x 4m. A possible internal layout for the apartment is suggested in Figure 3. To allow more flexibility in the arrangement of the apartments, we can accept that the large window in the living room can be placed on any of the three walls. Also, the entrance to the apartment can be moved a few metres along the wall without any problems.

Simplified abstract representations for these units will be used, as shown in Figure 4. The circulation block is represented by an open framework and the apartment by a grey box, with the darker end denoting the location of the living room.

In order to eliminate the possibility of the entrance being surrounded by built form and therefore rendered inaccessible, this building will not have any ground floor apartments. Consequently, the initial shape for this grammar becomes a stack of two circulation blocks.

In order to build upon the initial shape, there need to be rules that add shapes to the circulation block at the top of the initial stack. Contiguous circulation and accessibility for every apartment can be assured at the level of the shape grammar definition by using the last placed circulation block on the left hand side of every rule. Apartment blocks can be added to circulation in two different ways and a third rule can attach another circulation block to an already existing one. This creates a chain of circulation spaces which becomes the circulation core of the building. Figure 5 shows these three basic rules.

Explicitly defining the usable transformations of these rules produces a total of 22 rules, as seen in Figure 6. Rules 1 to 8 are rotations and reflections of the first basic rule on the horizontal plane, and rules 9 to 16 are rotations and reflections of the second basic rule. Finally, rules 17 to 22 extend existing circulation in all six directions. Although all these rules are not strictly necessary, as the same result could be achieved by adding labels to the first two rules, the variations are made explicit so that they can be used in the shape code.

Concept designs for apartment buildings can be produced using this shape grammar by starting with the initial shape and then applying rules sequentially. An example, showing the generation of a simple apartment building is shown in Figure 7. Each new stage in the sequence is the result of applying the rule designated above each arrow on the last placed circulation block.

Concept designs produced using the shape

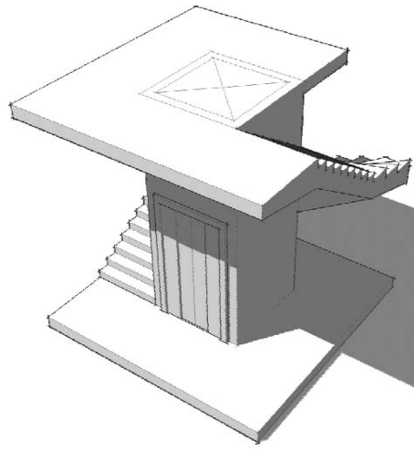

Fig 2. Example use of the circulation block

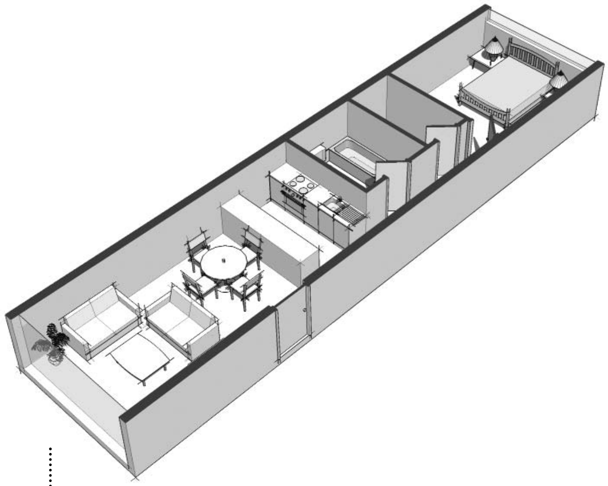

Fig 3. Possible internal layout for the apartment unit

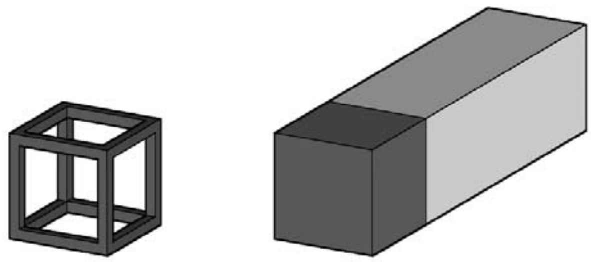

Fig 4. The two shapes in the apartment block shape grammar vocabulary

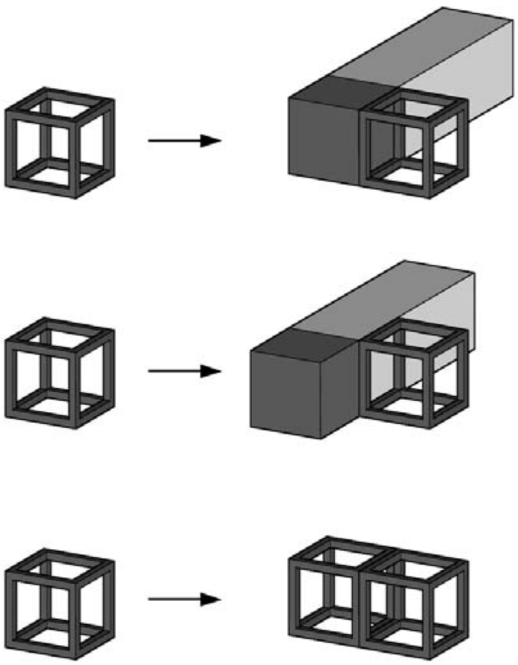

Fig 5. The three basic rules of the apartment block shape grammar

grammar described above display characteristics that can be described quantitatively and can be used to define a set of desirable characteristics for the optimisation of designs by Shape Evolution. Each design can then be scored by comparing its measured characteristics with the goal quantities. The graphical user-interface developed for inputting the goal values in shown in Figure 8.

The system uses three ways to represent each design. The first is the shape code string that describes the rule sequence that generated the design. This can be translated into a second representation, where a three-dimensional array is populated with integers that represent different kinds of cubic modules (0 represents a void, 1 represents a circulation block, and each room of the apartment is represented by numbers from 2 to 5). For the purposes of presenting a design to the user in an intelligible format, Shape Evolution converts the three-dimensional array into a VRML file which can be viewed interactively in an appropriate browser, as shown in Figure 9.

GENERATION OF THE INITIAL POPULATION

The genetic algorithm provides a mechanism to search the problem space but a random initial population must be provided. In order to generate this population, a user-defined number of random rules are selected and applied. As invalid rules are possible, the initial population generator must be discerning about how the random rule sequences are produced. Instead of trying to resolve this issue by

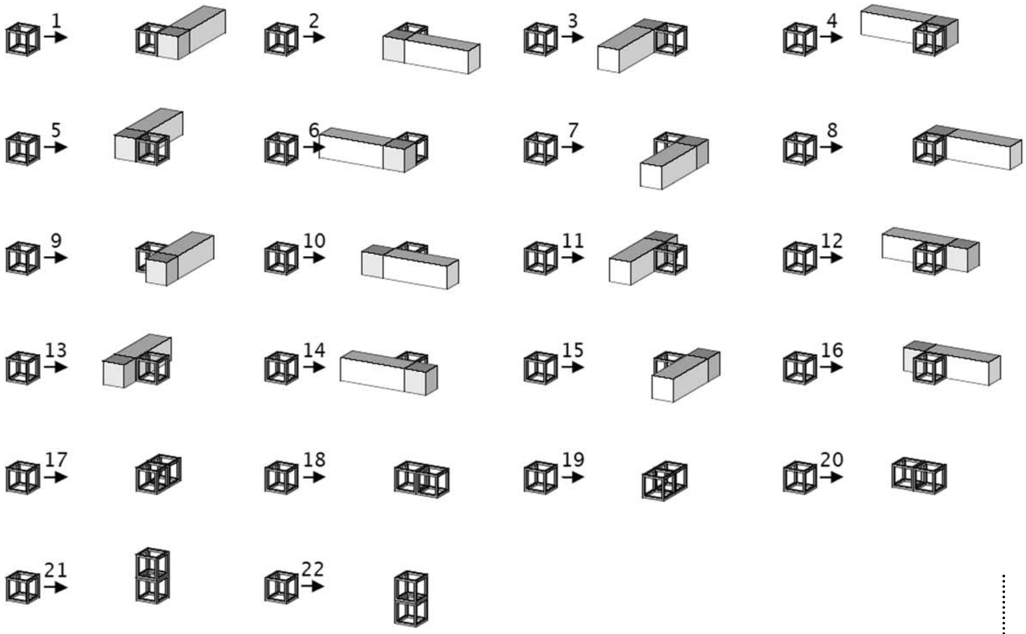

Fig 6. The 22 explicit rules of the apartment block shape grammar

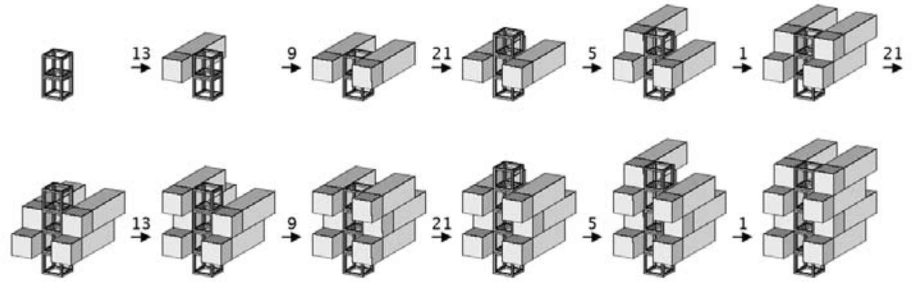

Fig 7. Example sequence of generation of an apartment building using the shape code 13 9 21 5 1 21 13 9 21 5 1

a knowledge-based system that defines which rules are applicable at a particular point in the sequence, the generator uses the three-dimensional information provided by the array representation to determine whether a rule application would create an invalid design. Adding this checking step ensures that all the array positions to be changed had originally a value of 0, i.e. that the was empty.

EVALUATION ALGORITHMS

The next step in the process is to evaluate the performance of designs in the initial population by comparing them with the user-provided optimisation goals. This task can be reduced to teasing information about a design's physical attributes from the already known data about the design: the three-dimensional array and the shape code. From these sources it is possible to extract the number of apartments, the area and volume of the completed building, along with its height and footprint. It is also possible to establish which apartments have unobstructed view from the living room and whether the stacking of the apartments provides an area outside the living room that could be used as a balcony.

The next phase in the genetic algorithm is to select, from the evaluated and scored population, the parents that will contribute genetic material to the next generation. In order to do this Shape Evolution implements a simple binary tournament selection scheme. The shape codes of the two parental genotypes that have been selected are bisected at a random position and the halves are swapped and rejoined to create the genotypes for the offspring. The parental genotypes are paired sequentially: the first individual is paired with the second, the third with the fourth, and so on. The crossover process fills the new population with valid individuals that are composed of genetic material

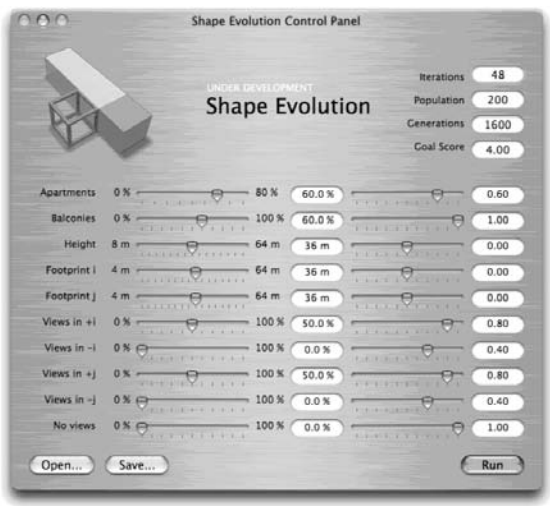

Fig 8. Unit interior design examples: Left. Luan Truong's design; Middle. Travis Louie's design; Right, Liko Dowling's design

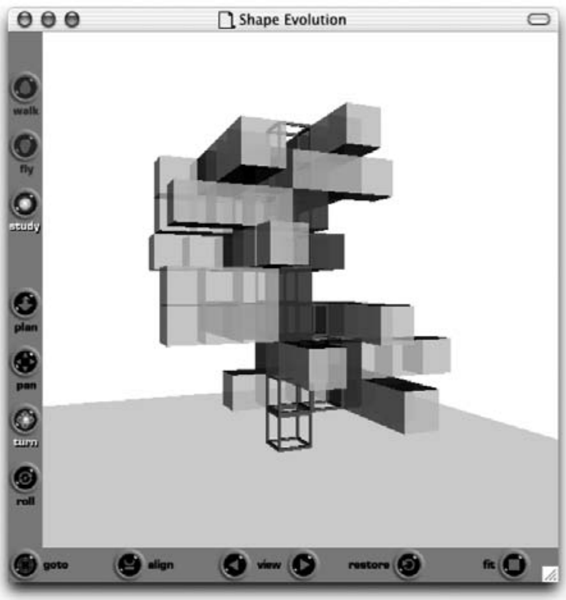

Fig 9. A typical apartment block design as viewed in a VRML browser

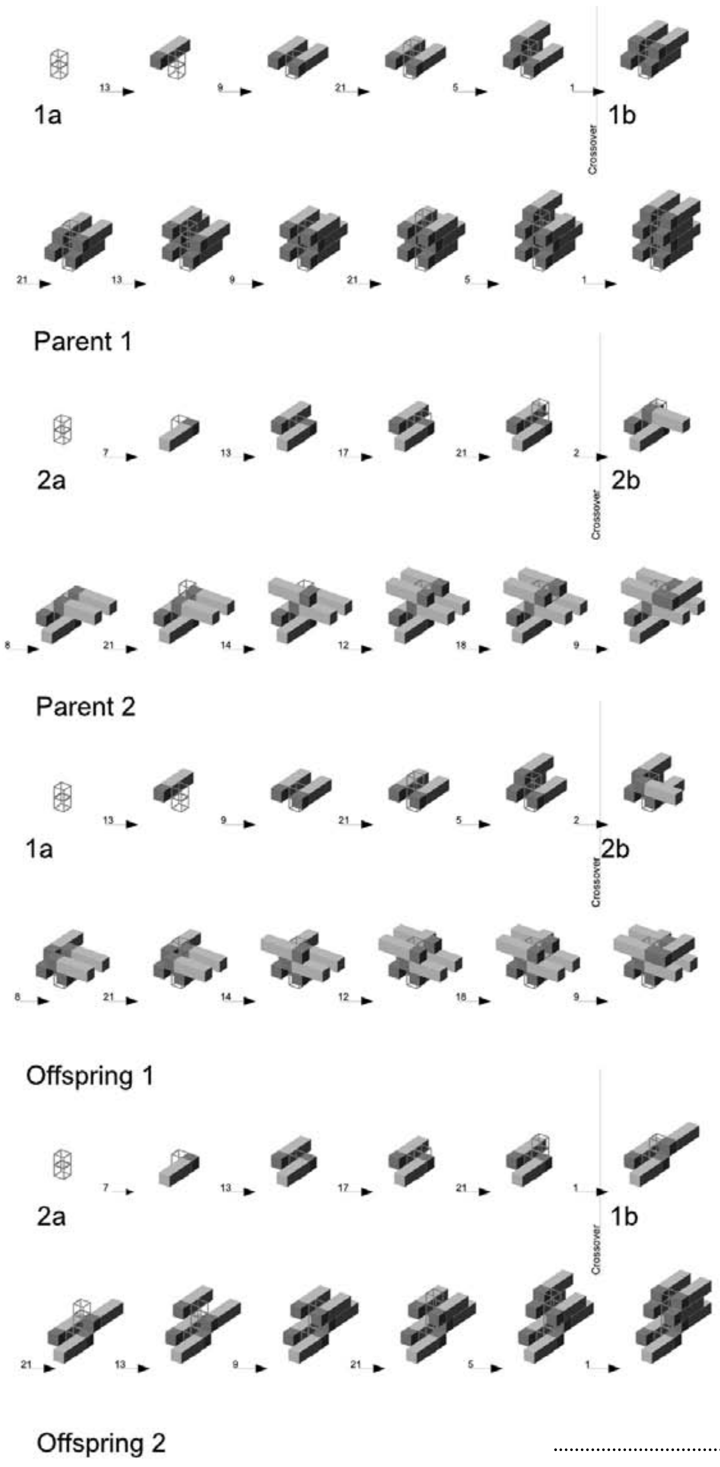

Fig 10.
Generating offspring from two parent genotypes

provided by the parents from the previous generation. Figure 10 illustrates how two parents are paired along with the resulting offspring.

The initial crossover point may result in invalid designs and, if this happens, a second crossover point is selected at random. This is repeated until either successful crossover is achieved or all possible crossover points have been tried, at which point the parents are returned to the population pool.

To introduce diversity into the new population and allow the exploration of new areas of the problem space, mutation is applied probabilistically. Every bit of every genotype in the population is capable of being mutated according to a user-defined mutation rate. Mutation actually involves changing the value of a particular bit to a random rule number from 1 to 22 and the mutation rate can be set by the user at any value between 0 and 1.

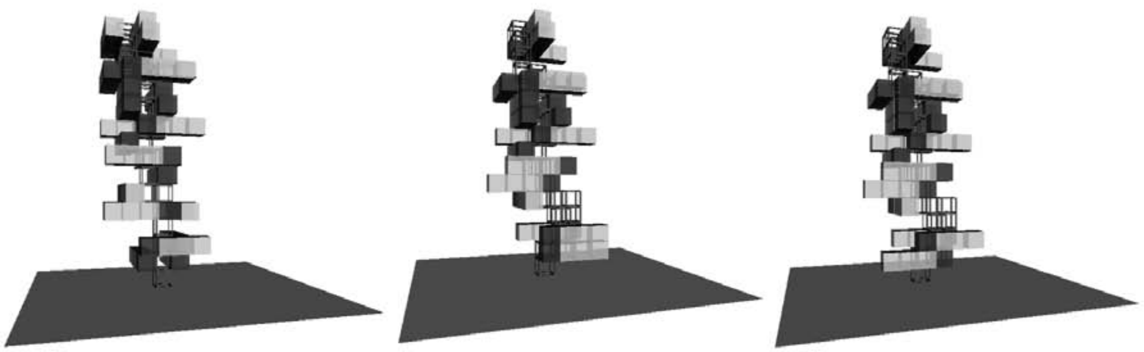

Fig 11.Some of the top designs produced for the tower block test

Each design that has been developed through the application of either crossover or mutation is converted into a three-dimensional array in order for it to be evaluated. As this process could also result in an invalid genotype the validity of each resulting genotype is checked to ensure that no clashes have occurred.

SHAPE EVOLUTION OUTPUT

Once the first new generation has been evaluated, its designs are scored, new parents are selected, crossover and mutation are applied, and another generation of designs is produced. This is repeated for either a user-defined number of generations (the end condition used in the prototype) or until a generation is produced with individuals whose score exceeds a user-defined threshold value. The results of the Shape Evolution run are then presented to the user. For the purposes of analysis, the prototype outputs an HTML document that collects and displays a significant amount of information about the last Shape Evolution run. Part of this information is the user-input variables: target values and weights for all criteria are presented, as well the population size, the number of generations, and the length of the genotype, i.e. the number of shape grammar rules used in each design. The user-defined value for the mutation rate is displayed alongside the actual mutation rate over all generations. The maximum score (a function of the various optimisation weights) is also shown.

A record is kept of all the champion designs. Shape Evolution does not produce ultimate, fully optimised solutions, so it would be deceptive to offer a single design at the end of its run. The purpose of the program is to inspire the designer by suggesting good solutions. Offering a number of alternatives does this, and also allows the designer a choice that can be influenced by criteria that were not dealt with by the Shape Evolution process.

TESTING SHAPE EVOLUTION

A number of design situations were used to test the Shape Evolution prototype with a selection of the evaluation parameters. As a basic goal, all designs attempted to minimize the number of apartments with blocked views. In each test Shape Evolution was run fifteen times, using a range of different settings for population size and mutation rate. For the purposes of this paper only one of the design situations will be considered: a tower block where the intention was to generate tall and thin buildings.

This was encoded by setting the goal value for

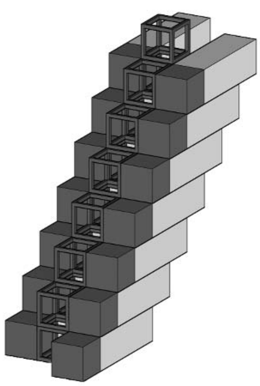

Fig 12. A design produced using Shape Evolution output as inspiration

the building's height to the maximum value, 64 metres. Both dimensions for the footprint were set to 24 metres, equivalent to six cubic modules. The weights for the height and the two footprint criteria were set to 1 and the genotype length was set to 48, meaning that 48 shape rules were applied to the initial shape. A series of runs were carried out with mutation rates set at values between 0.005 and 0.5.

In general, the building design concepts produced by the prototype were aligned with the design intentions. Furthermore, they presented novel solutions within the shape grammar defined for this class of designs. In this respect, the tool has been entirely successful: the designer has used a shape grammar and a set of design criteria as inputs and the program has generated a range of possible designs, which both meet the criteria and are interesting. For the purposes of experimentation with the Shape Evolution prototype, aspects of building functionality such as structural concerns, or the vertical continuity of elevator shafts were not considered. Still, for the most part, the requirements that were encoded were resolved successfully. Furthermore, the results display another positive trait, diversity. In most of the runs, the champion designs, i.e. the highest-scoring designs of all generations, were very different. Figure 11 shows some of the tower designs produced by Shape Evolution and Figure 12 shows one of the final designs.

In many of the test runs the genetic algorithm displayed a bias towards the exploration of new areas of the search versus the exploitation of high-scoring designs already existing in the population. This is not a desirable characteristic as it can lead to a fall-off in performance and changes to the genetic algorithm operators could be implemented in order to control this bias. Furthermore, the genetic algorithm performed more efficiently in the test cases where the design goals were not contradictory, as was the case with the tower block.

CONCLUSIONS

Having performed tests with the prototype, general comments can be made with respect to how Shape Evolution has addressed the original requirements. The goal was to produce a method and a tool that would be usable, i.e. fast and uncomplicated to its intended users, able to suggest functional solutions, and inspiring (by suggesting innovative design ideas). Also, by using shape grammars to generate the initial designs the tool satisfies another stated goal, the ability to produce designs consistent with the designer's stylistic and aesthetic requirements.

The test runs of Shape Evolution took several hours to complete. While the performance of the prototype may not be ideal, and a far cry from the envisioned real-time system, the reasons for this lie in the inefficient genetic algorithm code. The coding process was result-oriented, only aiming to produce working code, which inadvertently sacrificed efficiency.

Although this work is not the first to suggest that shape grammars and genetic algorithms can be linked, it has suggested a novel way in which this might be done; by using the shape code as the genotype. Shape Evolution allows for the definition of a design space by using a shape grammar, and only searches for solutions inside this space. This offers designers a significant amount of control over particular features of generated designs, namely the aspects of design that can be attributed to a particular style. Using computational power for what it can do best, Shape Evolution carries out a massively parallel exploration of the design space and this can yield high performance solutions.

Were Shape Evolution fully developed to the point where it could be made available to practicing designers, it could provide a powerful tool which would allow layouts of various kinds to be explored interactively. These could be at any level, from furniture layouts in a large open-plan space, through three-dimensional layouts of modular building components (as illustrated here), to the layout of large areas of cities. Its power does not lie in its ability to generate a specific solution, but to help the designer understand the boundaries of the world that he or she is exploring. When designing manually one might generate a few solutions and then choose the one that performs best. Shape Evolution has the ability to generate thousands of solutions and, as a result, the designer can learn how specific spatial characteristics relate to aspects of performance. The designer still has to choose

which of the various possibilities are worth exploring, but using Shape Evolution means that these possibilities are drawn from a much larger pool.

REFERENCES

BUELINCKX, H. 1993, "Wren's Language of City Church Designs: a Formal Generative Classification", *Environment and Planning B: Planning and Design*, 20, pp. 645-676.

GERO, J. S. and KAZAKOV, V. (1996). "Evolving Building Blocks for Design Using Genetic Engineering: a Formal Approach", in *Advances in Formal Design Methods for CAD*, Ed J.S.Gero J.S. (Ed.), Chapman and Hall, London, UK, pp. 31-50.

GOLDBERG, D.E. 1989, *Genetic Algorithms in Search, Optimization, and Machine Learning,* Addison-Wesley, Reading, MA, USA.

HOLLAND, J.H. 1975, *Adaptation in Natural and Artificial Systems,* University of Michigan Press, Ann Arbor, MI, USA.

KNIGHT, T.W, 1981, "The Forty-one Steps", *Environment and Planning B: Planning and Design,* 8, pp. 97-114.

KNIGHT, T.W. 1994, *Transformations in Design: a Formal Approach to Stylistic Change and Innovation in the Visual Arts,* Cambridge University Press, Cambridge, UK.

KONING, H. & EIZENBERG. J. 1981, "The Language of the Prairie: Frank Lloyd Wright's Prairie Houses", *Environment and Planning B: Planning and Design,* 8, pp. 295-323.

KOUTAMANIS, A. 2000, "Representations From Generative Systems", in *Artificial Intelligence in Design '00*, in J.S.Gero (Ed.), Kluwer Academic, Dordrecht, Holland, pp.225-245.

LOOMIS, B.A. (undated), *SGGA: a user-driven genetic algorithm for evolving non-deterministic shape grammars,* Available: http://architecture.mit.edu/descomp/works/SGGA0502.pdf

ROLLO, J. 1995, "Triangle and T-Square: the Windows of Frank Lloyd Wright", *Environment and Planning B: Planning and Design,* 22, pp. 75-92.

ROSENMAN, M. & GERO, J. 1999, "Evolving Designs by Generating Useful Complex Gene Structures", in P.J.Bentley (Ed.), *Evolutionary Design by Computers,* , Morgan Kaufmann, San Francisco, CA, USA.

SHEA, K. & CAGAN, J. 1997, "Innovative Dome Design: Applying Geodesic Patterns With Shape Annealing", *Artificial Intelligence for Engineering Design,* Analysis and Manufacturing, 11, pp. 379-394.

STINY, G. & GIPS, J. 1972, "Shape Grammars and the Generative Specification of Painting and Sculpture", in C.V.Freiman (Ed.) *Proceedings of IFIP Congress 71*, North-Holland, Amsterdam, Holland, pp. 1460-1465.

STINY, G. 1975, *Pictorial and Formal Aspects of Shape and Shape Grammar,* Birkhauser, Stuttgart, Germany.

STINY. G. & MITCHELL, W.J. 1978, "The Palladian Grammar", *Environment and Planning B: Planning and Design,* 5, pp. 5-18.

STINY, G. & MITCHELL, W J. 1980, "The Grammar of Paradise: on the Generation of Mughul Gardens", *Environment and Planning B: Planning and Design,* 7, pp. 209-226.

WOODBURY, R.F. 1993, "A Genetic Approach to Creative Design", in *Modeling Creativity and Knowledge Based Creative Design,* J.S.Gero, & M.L.Maher, Lawrence Erlbaum Associates, New Jersey, NJ, USA pp. 211-232.

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A COMPUTATIONAL ARCHITECTURAL DESIGN MODEL BASED ON FRACTALS

Özgür Ediz & Gülen Çağdaş

Abstract

Digital design technologies play a significant role in assisting the designer through conceptual architectural design. Computer supported design systems can generate various images at the early design phase and can contribute to seeking alternative architectural forms. Currently, different design approaches are being employed in the formation of architectural products. Examples of architecture that produce unusual forms are often encountered within unique conceptual approaches. The development of new design examples is supported by the digital production of forms, and three-dimensional models through varying geometric approaches. In this study, a design approach that uses computer aided architectural design to produce architectural forms will be suggested. This approach utilizes principles existing in the unique fractal dimension of elements based on a vocabulary relevant to a specific architectural language. By relying on the fractal dimension and features of an existing architectural pattern, this generative design approach supports creativity in the production of new forms. The proposed approach is evaluated as a creative tool in architectural design. The subject of architecture; buildings, spaces, surroundings, symbols of that particular society are also the elements of a meta-language which creates a fractal geometry based relation. It is possible to analyse this relation through a fractal geometry-based principle. In short, a fractal geometrical generative method is suggested. Also, recently-surfaced discussions about "Chaos Theory" and its effects on the design process via "Chaos and Self - Similarity" are studied. The significance of these different phenomena and disciplines upon architectural design are also studied for developing a possible creative tool.

Keywords: *Architectural Design, Computer-Aided Architectural Design, Fractal Geometry, Generative Approach, Architectural Languages, Architectural Grammar, Chaos Theory.*

INTRODUCTION

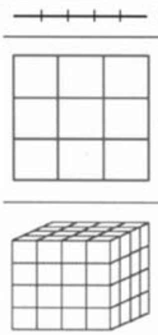
Contemporary architecture has been affected by the concepts of fractals and self-similarity discovered through "Chaos Theory". When examples of contemporary architecture are examined in this sense, it can be seen that various previously unencountered and unfamiliar forms appear, and that in the universal sense, there are architectural approaches seated on very different facts. Examples of contemporary architecture are in fact quite different from the architecture of the recent past. In this architecture, forms from Euclidean sources are not found and the new designs are formed from "fractals, wave formations and various concepts forming the Cosmos" (Jencks, 1997; Cathcart, 2002).

This idea of Jencks' is completely compatible with concepts of pluralism and complexity. Cultural pluralism must present different tastes, and different ethnic pasts and economic groups still motivate architecture. Besides, Alexander Koyre's view that "After the Greeks' discovery of the Cosmos, the greatest revolution which exists is the destruction of the Cosmos" (Bumin, 1996) has the quality of supporting this idea which appeared with "Chaos Theory", called by Jencks "Cosmic Evolution".

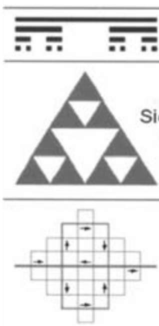
Fractals lie at the foundation of the self-similarity concept which appears with Chaos. The term fractal comes from the Latin 'fractus', which when translated into English is taken to mean piece, break, broken, fragment, fractional, and disorder. B. Mandelbrot put forward the idea of fractal geometry in the 1980s, and showed us a completely different structure to Euclidean Geometry (Mandelbrot, 1982). The concepts of uncertainty and disorder which appear with Chaos Theory are the basic concepts forming fractals. The accuracy and rigidity of Euclidean geometry are absent from fractals (Table 1).

In another sense, the basis of creative architectural design models conforms to Chomsky's studies in language theory. Just as there are rules for the organization of words in language, so are there

Euclidian Geometry	Fractal Geometry
Traditional (>200 years)	Modern (~25 years)
With a characteristic measurement	Without special size and measurement
Applied to simple objects	Applied to natural forms
Described by a formula	Described by a (recursive) algorithm



	r	N	$N=r^D$
line	5	5	5^1
square	3	9	3^2
cube	4	64	4^3



	D_T	r	N	$D_S=\frac{\log N}{\log r}$
Cantor Set	0	3	2	0.63
Sierpinski Gasket	1	2	3	1.58
Peano Curve	1	3	9	2.00

Table 1. Euclidean and fractal geometry (Adapted from Özsarıyıldız, 1991)

certain rules related to the organization of elements in architectural language (Chomsky, 1965). In the context of architecture and geometry, extensive research related to shape concepts has been conducted in the past. A design product and architectural elements belonging to an architectural language, the syntax, semantics, context and style framework which contain the rules used in the formation of products from these elements, are produced (Schmitt, 1988).

Parallel to the syntactical and semantic features which Chomsky has revealed as existing in language, Steadman also examines scientifically in two articles the syntax concerned with architectural linguistics, the formation of architectural shapes and arrangements, and the semantics related to the meaning of these arrangements (Steadman, 1983).

In models used in the generation of architectural designs in a computer environment, these two features are modelled from two different approaches:

- Models generating topological and geometric definitions of design,
- Models ensuring the compatibility of design definitions with performance necessities.

In the scope of this study, the use of a theoretically developed generative approach in the production of architectural forms, based on an existing architectural language, that aims to support creativity, has been aimed. In this regard the model generates the topological and geometrical definitions of the designs. The forms generated can be interpreted as an architectural design product by integration with the context, the adoption of functional features, and the evaluation of performance necessities.

CONCEPTUAL APPROACHES TO USING FRACTALS IN ARCHITECTURAL DESIGN

Fractal concepts displaying a self-similar structure are often encountered in the field of architecture. By approaching a structure from its mass, right down to the smallest components of its internal mechanism, it can be seen that it possesses many self-similar details. Gothic architecture is in this sense a good example. On examination it can be seen that the capital of the column of a Gothic cathedral is a miniature copy of the cathedral itself. This is identical to the way a palaeontologist can deduce the entire skeleton of a dinosaur by making use of its rear bones. In this way it is possible to estimate the whole cathedral from its components. In fact this structure, formed from self-similar elements and often encountered in the history of architecture, is fractal architecture.

Fractal geometry has recently begun to be used with the aim of supporting a new approach in generative architectural design. Concepts based on fractal geometry can be represented in a comput-

erised environment by efficient algorithms and are used in the formation of surfaces and structures.

Shape grammars are used nowadays in several different ways with regard to supporting creativity and with the aim of novel design in generative architectural design approaches. Fractal approaches, however, as a particular application field of shape grammar, are represented in the scope of computer-aided design and in a computerised environment by generative algorithms.

In the field of computer-aided architectural design, fractals are recognised as a sub-group of shape grammars, used as a device to aid form generation and representation. When compared with shape grammar, fractals are a means of aiding geometrically characterised design, in which a smaller number of rules is used, but with a greater repetition of rules and a high property of self-similarity of shape (Schmitt and Chen, 1991).

In fractal geometry, the basic shape generated is repeated by an algorithmic structure, resulting in its transformation into a complex structure. This algorithm generates an initial state, and by means of a generation rule applied to this initial state, it generates self-similar shapes (Çagdas, 1994).

In the example seen in Figure 1, the initial shape is part of a bow. The generation rule applied to the initial shape is formed from infinite recurrences and produces the fractal perception. Because neither meaning nor function has been given to the shapes, the formal perception in this example shows syntactic and shape characteristics.

Moreover, fractals display perfection in the definition of existing patterns. In this way, in the context of "Fractal Dimension", it is possible to examine these patterns and obtain the syntactic design knowledge belonging to them. These patterns may be natural patterns as well as architectural patterns. This characteristic supports the view of profiting from traditional and existing shape models in the formation of design concepts by considering architectural sub-cultures (Abel, 1988).

Among the people who have seen the potential of fractals and fractal geometry as a practical tool in architecture, and who have done research in this field are Chris Yessios and Peter Eisenman. Yessios states that computers could be used as a means of generating and discovering architectural forms.

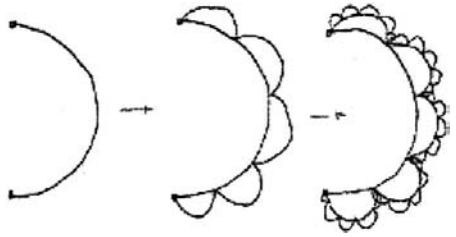


Fig 1. N. Salingaros's fractal concept (Salingaros, 2002)

Yessios uses fractal geometry, arabesque ornaments and the DNA/RNA biological process as a fractal generator. In this way Yessios developed fractal software which remains faithful to the same root with several generators and which can reiterate itself several times (both forwards and backwards) (Yessios, 1987).

M. Ibrahim and Krawczyk, however, with their ideas of formation of spatial organisation dependent on fractal geometry, made use of the design principles found in J. L. Durand's book "Précis des lecons d'architecture". By taking up the "snowflake" shape which possesses fractal properties, they reorganised the schemes which depend upon these principles. (Ibrahim and Krawczyk, 2000)

In the scope of the study, by relying on the fractal dimension and features of an existing architectural language, and by the generation of new forms which will ensure the continuity of the language, a generative approach aiding design has been developed. This approach, which reflects the topological and geometric features of architectural design, must be supported with algorithms which, by integrating them with the context, are directed by functional requirements.

CALCULATING FRACTAL DIMENSION AND METHODS OF GENERATING A FRACTAL PATTERN

In order to establish fractal dimension in an existing architectural perception, the "Box Counting Method" has been used (Bovill, 1996). This method takes into consideration the wealth of detail and the repetitions of the perception examined. The fractal dimension calculated by the box counting method is determined by counting the boxes containing lines in which data are found and calculating their

number in proportion to that of the empty boxes. As the size of the grid formed for this purpose decreases, so the number of boxes containing data increases. The full and empty boxes found at the next stage are inserted into the following formula[i] and the fractal dimension is obtained.

$$D= \log(a)-\log(b) /\log(c)-\log(d)$$

The fractal dimension obtained by the box counting method, while giving clues to the pattern, can also be used in the formation of new patterns. In the pattern researched or the new formation envisaged, by using the principles of the elements found in a known architectural shape dictionary and those of fractal theory, the developed generative models can be used in the generation of architectural forms and in architectural design in a computer environment. It is expected that the above approach would support creativity.

The new patterns to be formed can be generated with the "Curdling Method" as possessing fractal perception. The Curdling Method is a method which Mandelbrot has used in the process of forming a kind of fractal stain. The fractal stain aids the separation of points showing common features or a group of shapes from each other. The formation of fixed star clusters, which appear to be grouped randomly in the star systems of the sky, can be clarified with the Curdling Method (Bovill, 1996).

A GENERATIVE APPROACH BASED ON FRACTALS IN ARCHITECTURAL DESIGN (CADaFED)

In this study, by examining design-based geometric concepts of structures and examples belonging to an existing architectural language, an approach based on fractal geometry is suggested which may aid the generation of new designs. In this framework, the intention has been to generate arrangements which will pave the way to the definition of the basic grammar rules forming an architectural pattern, by the analysis of similar design examples, and, with the support of these rules obtained, to the generation of new designs. It is considered that the suggested design may be of support to creativity, in the context of searching for form, in the generation of new original patterns, by defining the original pattern language of the existing environment with fractal geometry. In the development of this approach, the following stages have been carried out:

- Using the Curdling Method, an algorithm has been developed which is formed from a selected unit and with the intention of forming different settlement patterns displaying fractal features.
- A generative algorithm has been developed which creates different forms by applying different scales to a geometrically-defined initial shape.
- With the aim of producing data for the application of the algorithms developed, an existing architectural pattern has been selected. By examin-

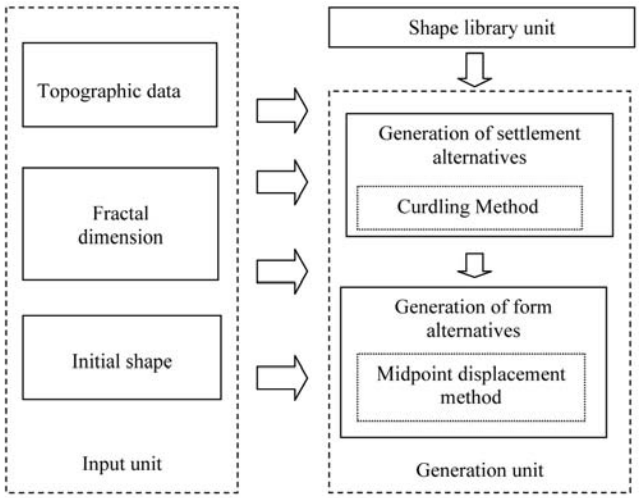


Fig 2. The structure of the CADaFED

[i] D: fractal dimension
a: number of full boxes counted at next iteration.
b: number of full boxes counted at previous iteration.
c: number of boxes on bottom row occurring at next iteration .
d: number of boxes on bottom row occurring at previous iteration.

ing the Fethiye / Kayaköy settlement, its fractal features have been established through the box-counting method in its settlement, street and dwelling scales. This settlement in Turkey was chosen for its characteristic architectural pattern.

● By means of the fractal dimension of the Kayaköy settlement and of a selected street pattern, alternative solutions have been produced which will ensure the continuity of the pattern in new design projects, by applying the typological and fractal features of the dwellings to the algorithms developed.

The CADaFED (Computational Architectural Design approach based on Fractals at the Early Design phase) model described above consists of five main units: (Figure 2) (Ediz and Çagdas, 2004)

● Input unit: (1) topographic data of the existing site, (2) fractal dimension of the existing pattern, (3) initial shape (A cube has been chosen for this study. The dimensions and quantity of cubes can be varied).

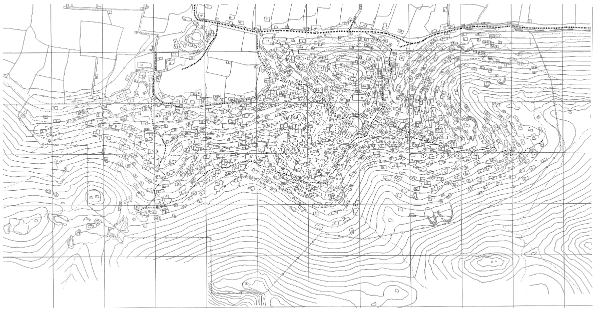
● Shape library unit: varying dwelling forms that exist on site.

● Generation unit: (1) settlements generated by the curdling method, (2) forms generated by "Archimedes' midpoint displacement method".

● Settlement output unit.

● Animation unit: generated by the Direct X code.

In order to apply the suggested approach, the fractal dimensions of first of all the settlement, then one of the streets of this settlement and finally the dwellings in this street possessing a dissimilar plan concept have been calculated. The dimensions, obtained by means of the box counting method, have been interpreted on the settlement, street and dwelling levels. As a result of this evaluation, the existence of the continuity of the pattern has been investigated, and the relationship between dwelling and topography has been examined. The values obtained with the calculation of fractal dimension have been used as data for the new pattern to be created. In the generation of the new pattern, the fractal dimension obtained from Kayaköy, has been used as data in the generative algorithm.



The calculation of fractal dimensions of settlements in Kayaköy

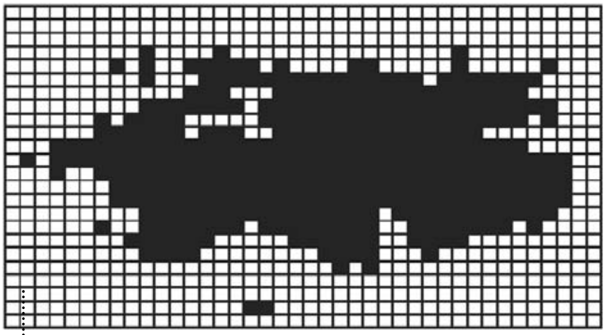


Fig 3. Pattern formed by box counting method as a result of the fourth stage in the general settlement scale.

Iteration	Total boxes	Empty boxes	Full boxes
1. Iteration	60	24	36
2. Iteration	240	120	120
3. Iteration	960	585	375
4. Iteration	3840	2681	1159

Table 2. Pattern formed by box counting method as a result of the fourth stage in the general settlement scale.

Fractal dimensions of the existing settlement

For the calculation of the fractal dimension of the settlement, first of all the plan outlines of the dwellings on the site have been drawn; the existing street - and wall - patterns, and the contours have been shown on the diagram. Consequently, the "stains" forming the settlement have been brought to light (Figure 3).

The full and empty boxes obtained after each stage are shown in the table below (Table 2).

When the values obtained are applied to the formula mentioned above for calculating fractal dimensions, a fractal dimension of 1.627 is found.

Fractal dimensions of the street
From the existing Kayaköy settlement, the fractal dimension of which has been calculated, the fractal dimension of a street selected from this area has also been calculated. Thus, the continuity of the fractal perception in the settlement and street scales will have been examined.

In the selected street, a great majority of the types of dwellings forming the Kayaköy settlement are found. In the diagram describing the dwelling plans, the contours, garden walls of the dwellings and all the data constituting the architectural structure have been taken into consideration. The fractal dimension has been calculated with the box counting method. Initially, a 4 X 5 grid system has been established to utilize in the first iteration to identify the architectural forms of the street patterns; followed by a finer grid constituting of multiples of 2 until no significant changes are observed in the fractal dimension.

The fractal dimension obtained by the above operation is found to be one of "1.438", a value quite close to that of the general settlement. This dimension obtained, shows that the fractal perception existing on the settlement scale also shows continuity in the relevant pattern examined on the street scale. As a result of this operation, it is possible to say that there is a link between the general settlement and the streets. In the analysis of the settlement, the link in question has the quality of providing evidence of the continuity of the pattern on both these scales.

Fractal dimensions of the dwellings
At this stage of the study, by examining dwellings in different perceptions, the calculation of their individual fractal dimensions is dealt with. As such, the intention has been to examine how fractal dimension varies between different types of dwellings. The fractal dimensions found for the dwellings in question, show variances from 1 to 1.42. An examination into fractal dimension for five different dwellings shows higher fractal values for those dwellings with wealth of detail.

Creating a settlement plan based on fractal approach
The creation of algorithms aimed at generative architectural design was begun with the collection of plans, which formed an architectural shape grammar library. The finding of separate typological features of each room in every dwelling and of individual units was assisted by the formation of a shape dictionary (Saraç, 2001).

The algorithms developed for the formation of generative fractal settlements have been written in the "C++" computer programming language. The algorithms developed have been produced by two different approaches, with the combination of syntactical and shape characteristics, independent of the area selected for the application and faithful to the fractal dimension of the area.

The fundamental characteristic of the algorithm to be used is that it is independent of location, and permits the design of new forms developed outside the context of Kayaköy. The natural environment considered in this context deliberately displays a level topographical characteristic. In this study, one of the dwelling types found in streets in Kayaköy has been selected. Thus, by changing the fractal dimension, the way has been paved for the formation of model settlements. In the algorithm formed independently of the area, a total of five basic generative algorithms have been developed. Each of these algorithms forms a settlement concept with different characteristics. In establishing the imaginary placement of the dwellings, the Curdling Method has been used. The distinction of these five algorithms from each other is the difference between their probability factors. Village (xxx) programs are established through three different stages by the Curdling Method: (Ediz, 2003)

Stage 1: At this stage the settlement area is divided into a configuration formed from a total of 16 squares according to a 4x4 grid system. Then some of these squares are eliminated at random.
Stage 2: The squares remaining from the first-stage elimination are used at this stage. These squares are divided into smaller squares, which form 2x2 (four-square) grids, and some of these are eliminated by the same method used in the first stage.
Stage 3: The squares which were not eliminated at the previous stage are again divided by

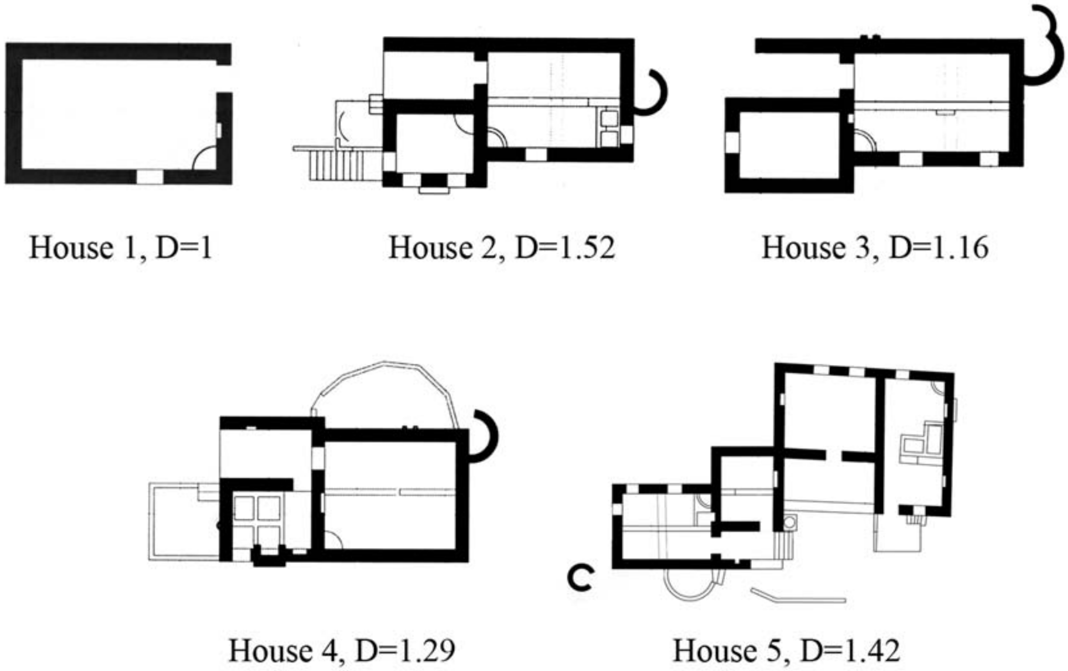


Fig 4. Fractal dimensions of settlements in an existing pattern

forming four-square grids; again some of these are eliminated. Finally the selected dwelling unit is established on the remaining squares (plots). The distribution of the settlement formed has a structure with a strong fractal value (Figure 4).

The "xxx" numbers at the end of the name of the developed programs shows the elimination ratios of that program. For example in Village 232, almost one box out of two is eliminated at the first stage. At the second stage, two boxes out of three are eliminated, and at the last stage, again one box out of two remains. By altering these ratios it is possible to arrange the distribution of the diversity of the settlements. In this context the distinction between the generative algorithms formed is the different elimination ratios at each of the three stages. At each operation of these programs the same fractal characteristic (such as in 232) but a different settlement arrangement is encountered. Several variables supporting design (landscape, direction, etc.) can be added to the algorithm.

When a desired settlement concept is attained, the operation of the program forming fractal patterns is terminated. Village 232, as a result of the above operation, displays only one of the infinite settlements obtained (Figure 5).

The algorithms formed which are dependent on the site, however, have been formed by taking into consideration the fractal dimension of the existing streets and the topography of Kayaköy (Figure 6). The existing pattern of the Kayaköy settlement materializes from several different criteria; one of which is topography; that is to say, the natural physical environment.

The Kayaköy settlement was formed on hills of different altitudes facing away from the sea. The hills formed the gradients of the topography and the streets emerged dependent on this criterion. The streets were developed parallel to the slopes and in a way which would ensure access to the hills in the

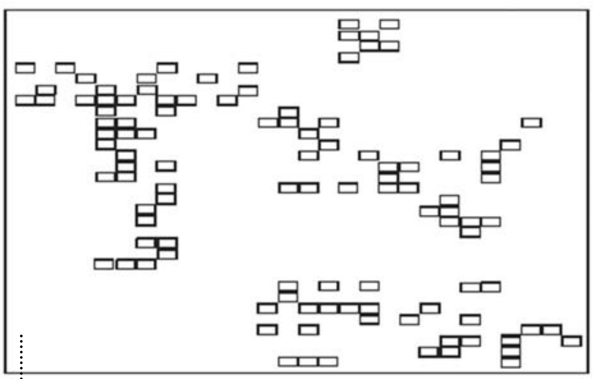


Fig 5. Independent of the area, generation of a settlement pattern in an artificial 'flat' topography, Village (Curdle) 232.

Fig 6. Example of settlement-pattern generation, dependent on the area, according to Curdle 232, in an artificially-inclined topography.

lowest possible gradient.

In the generative algorithm developed, three hills which ensured the formation of the rows of streets of Kayaköy were conceived. At the next stage three separate dwelling types found in Kayaköy were selected for the purpose of this study. The selected dwellings, by taking the hills formed as a base, formed the new pattern of the streets and the settlement in the fractal dimension, which is different from the existing layout of Kayaköy (Figure 6).

Creating form alternatives based on the fractal approach

With the aim of forming architectural forms showing fractal features, various algorithms have been developed using the "C++" computer programming language. Fractal theory was formed by means of Archimedes' "Midpoint Displacement Method". The developed program, by using the "Direct X" (code) for every fractal dimension, creates an animation of forms revolving around themselves. With the aim of increasing the legibility of the alternatives, various colours have been highlighted in order to form contrast, light and shade. As such, it is possible through the animation to observe clearly the emergence of the fractal concept. The developed algorithms, as in the algorithms for the generation of the settlement, possess two different concepts, namely dependent on and independent of the location.

The algorithm designed independently of the location generates different form alternatives by

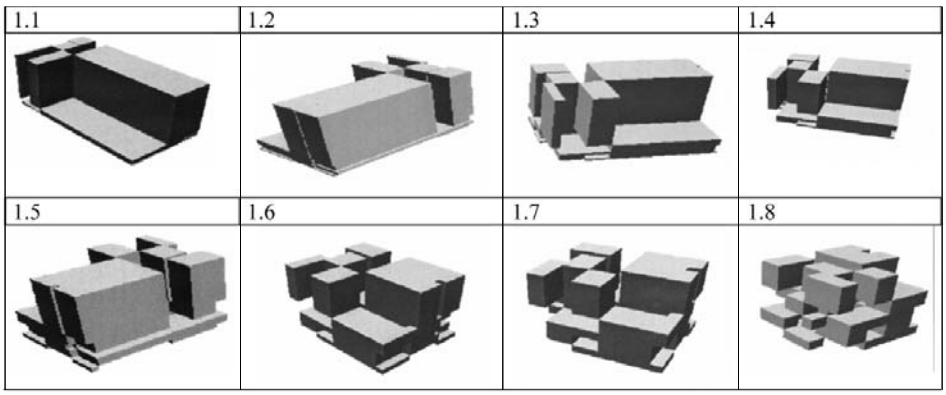


Table 3. Block design based on fractal dimension

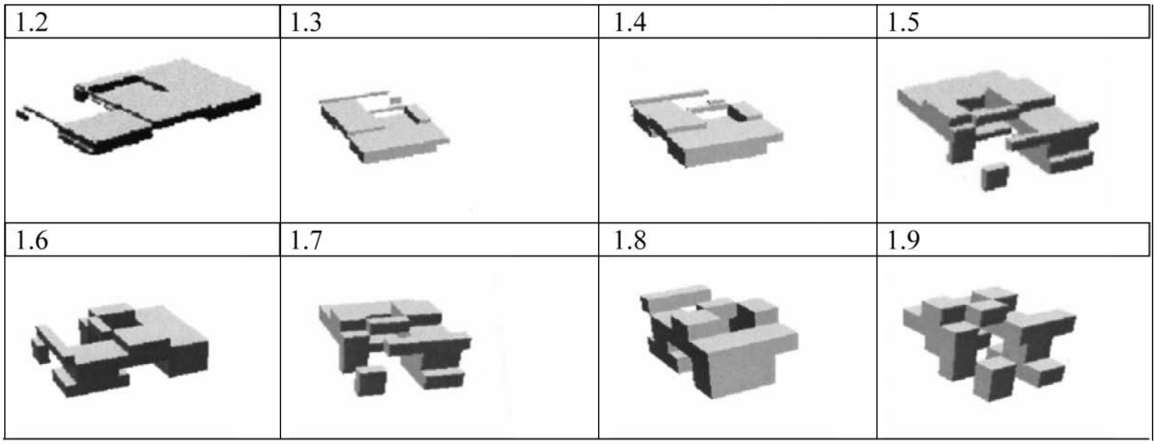


Table 4. Block changes in Dweling 2

means of a change in the fractal dimension. As an initial form in the formation of the settlement, the most basic geometric shape, namely the cube, has been used. By way of forming 125 groups of these cubes, block formations having fractal values from 1.0 to 1.9 have been created. In Table 3, it can be seen that as fractal value increases, the cubes create a more complex form, but as fractal value decreases, the cube group, by being less broken up, creates forms which can be defined by Euclidean geometry (Table 3).

With the aim of applying fractal theory to the existing architectural pattern, Dwelling 2, the fractal value of which had been observed previously, was examined; and by means of changing fractal dimension, different alternatives were produced. The original spatial concept of Dwelling 2 was examined in the context of the forms which would appear, by means of changes in fractal value from 1.0 up to 1.9. At a fractal dimension of 1.0, Dwelling 2 preserves its original form effect. As fractal value is increased, so the block activity of the dwelling increases (Table 4) (Ediz and Çagdas, 2005).

Algorithms for generative design

In computational architectural design, form investigations supporting creative thought can be carried out by means of generative algorithms. In the scope of this study, the algorithm developed for generating abstract forms presents various alternatives depending on different fractal dimensions. For this algorithm, form alternatives have been created which, by the application of fractal values belonging to an existing architectural pattern, will be able to reflect the continuity of the pattern in fractal concepts. The other algorithm developed here, the algorithm aimed at forming the settlement plan, has been examined for suggestions aimed at forming stains in the settlement theme, only by relating with the topography of the blocks to be generated.

CONCLUSION

The fractal geometry and fractal concepts which have appeared through Chaos Theory affect contemporary architectural understanding in different ways. Fractal concepts have come to be used in many ways, both consciously and unconsciously, in the field of architecture. Spatial configurations, which have been represented by constraints or rules in the abductive approach, have been represented by generative algorithms in the generative approach.

In this study, by relying on the fractal dimension of an existing architectural pattern, and at the early conceptual design phase, a generative design approach has been suggested which can be used for supporting creativity in producing new forms. However, using the fractal dimensions of elements found in a shape library belonging to the relevant architectural language, this approach may enable the creation of architectural forms which will ensure the continuity of the existing pattern. Different form alternatives can be generated by changing the fractal dimension. However, it is necessary to apply the functional features to the generated forms by relating them to the context and to develop them as an architectural design product by evaluating them

according to their performance requirements.

Using digital technologies when searching for alternative forms in the conceptual design phase is a new approach based on the development of new technologies. Using digital media as design media gives the designer the opportunity to extend his/her imagination and innovations. In further research, by placing the three-dimensional form alternatives at the settlement model, harmony can be tested with the existing architectural language.

The architectural design process is made up of several dimensions different from each other. Designing new forms through the use of existing architecture is only one of these dimensions. It is necessary to introduce functional features to these generated abstract forms by associating them with the context they are in. Further, the generated forms should be developed as architectural design products by taking architectural needs into consideration.

REFERENCES

ABEL, C. 1988, *Analogical models in architecture and urban design*, METU, JFA, 8, 2, 161-188.

BOVILL, C. 1996, *Fractal geometry in architecture and design,* Birkhauser, Boston.

BUMIN, T. 1996, *Tartisilan Modernlik: Descartes ve Spinoza,* Yapi Kredi Yayinlari, Istanbul.

CATHCART, M. 2002. *Architecture profile: Charles Jencks* (Online. Retrieved 12/13/2001: http://www.abc.net.au/arts/today/stories/s248345.htm)

CHOMSKY, N. 1965, *Aspects of the theory of syntax,* MIT press, Cambridge.

ÇAGDAS, G. 1994, *Fraktal Geometri ve Bilgisayar Destekli Mimari Tasarimdaki Rolü, CAD+ Bilgisayar Destekli Tasarim ve Ötesi,* 23, 28-31.

EDIZ, Ö. 2003, *A Generative Approach in Architectural Design Based on Fractals,* PhD Thesis, Institute of Science and Technology, Architectural Design Graduate Program, I.T.U (Advisor: G. Çagdas)

EDIZ, Ö., ÇAGDAS, G. 2004, *"A computational architectural design approach based on fractals at early design phases",* pp. 635 - 640, ECPPM: eWork and eBusiness in Architecture, Engineering and Construction, Taylor & Francis Group, London.

EDIZ, Ö., ÇAGDAS, G. 2005, *A generative approach based on fractals in architectural design,* ITU Journal / a, Vol: 4, no: 1, pp: 71-83.

IBRAHIM, M. M., and KRAWCZYK, R. J., 2000. *Generating Fractals Based on Spatial Organizations,* Illinois Institute of Technology College of Architecture, Chicago, IL USA.

JENCKS, C. 1997. *The Architecture of the Jumping Universe: A Polemic : How Complexity Science Is Changing Architecture and Culture,* Academy Editions, London.

MANDELBROT, B. B. 1982, *The Fractal Geometry of Nature,* W.H. Freeman And Company, New York.

ÖZSARIYILDIZ, S. 1991, *Conceptual Design by Means of Islamic-Geometric - Patterns within a CAAD-Environment, PhD Thesis,* TU-Delft.

SALINGAROS, A. N. 2002, *Fractals in the New Architecture* (Online. Retrieved 2003: http://www.archimagazine.com/afratta.htm)

SARAC, H. 2001, *Kayaköyü Konutlarinin Koruma ve Restorasyon Sorunlari, Yüksek Lisans Tezi,* ODTÜ, Fen Bilimleri Enstitüsü, Ankara.

SCHMITT, G. 1988, *Microcomputer Aided Design for Architects and Designers,* A. Interscience publication. USA.

SCHMITT, G., CHEN, C.C. 1991, *Classes of Design - Classes of Methods - Classes of Tools,* Design Studies, 12, 4, 246 - 251.

STEADMAN, P. 1983, *Architectural Morphology,* Pion Ltd., London.

YESSIOS, C. I., 1987, A Fractal Studio. *ACADIA '87 Symposium Proceedings,* 169 -181.

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A STRUCTURED ANALYSIS OF CAAD EDUCATION

Şule Taşlı Pektaş

Abstract

After more than four decades of its beginnings, Computer Aided Architectural Design (CAAD) has already reached a level of maturity in both the education and the profession. There is an ever-growing amount of literature on the subject; however, relatively few studies have taken a systematic approach to analyze CAAD education. Moreover, design institutions often view CAAD merely as a technical issue ignoring socio-cultural and theoretical aspects. In order to alleviate these problems, this paper presents a structured analysis of CAAD education based on Prof. Necdet Teymur's theory of architectural education. Prof. Teymur claims that the components of architectural education should be studied in terms of objectives (why), contents (what), methodology (how) and management (who) along with four different knowledge and disciplinary levels (viewpoints); namely, sociological, ideological, epistemological, and pedagogical. In this paper, current issues of CAAD education are addressed within this framework and several proposals are presented.

Keywords: *Computer Aided Architectural Design (CAAD) Education, Architectural Education Theory, Curriculum, Design Studio, Integration*

INTRODUCTION

The impacts of information technologies on information-based fields tend to be profound and revolutionary. It was widely recognized that building design is an "information processing" activity after the pioneering work of Akin (1986). The principal requirement of any building design project is evaluating and processing information and communicating that information between the parties involved. Hence, the utilization of information technologies in architectural design, widely known as Computer Aided Architectural Design (CAAD), has the potential for affecting processes and products of the discipline as well as its education. There is a considerably large -and ever growing- body of literature on the subject; however, it is observed that few studies have used a systematic approach to discuss CAAD education. In order to alleviate the problem, this paper presents a structured analysis of CAAD education based on Prof. Necdet Teymur's system (1997; 2001) for scrutinizing architectural education.

Teymur (2001) recognizes that architectural education has been handled as a "practice without theory." In order to elevate architectural education debates from the level of mere experience to that of structured, systematic and critical analysis, he recommends "problematization." When architectural education is defined as a "problem," it inevitably calls for theory. Teymur argues that such theories can not be directly borrowed from education discipline not only due to the lack of interest in professional education in that discipline, but also due to the peculiarities of architectural education. Aiming at a reconciliation of several concerns, he suggests that analyses of architectural education can be organized within the framework of four basic questions: objectives and motivations (why), contents (what), methodology and medium (how) and management and staff (who) and different knowledge and disciplinary perspectives; namely, sociological, ideological, epistemological, and pedagogical (Teymur, 1997; 2001). His theory is based on a simple set of concepts and questions that already exist in educational studies piecemeal (Lawton et al., 1978; Salama, 2006), however, as a whole it represents a unique and validated approach. The International Union of Architects (UIA) adopted Teymur's system as a framework for discussing issues related to architectural education (UIA, 2002). It was also applied in implementation of web-based design studios (Sagun et al., 2001).

The present study utilizes the theory as a tool to raise questions about the several aspects of CAAD education. Given the large body of the literature on

the subject and the diversity of educational approaches to CAAD, providing a structured analysis of the current topics of CAAD education is a difficult endeavour. Therefore, only the most important considerations could be discussed under each title. Predictions about the future of CAAD education and suggestions for further research are also made in this paper.

OBJECTIVES AND MOTIVATIONS

The first step of analyzing CAAD education is to understand "why" it is important. We believe that the increasing importance of CAAD is largely due to the new possibilities and modes of design thinking that it brought to architectural design. Earlier conception of the use of computers in design was the vision of a tool which "assists" existing design processes (Mitchell, 1994). During the 1980s, computers have been increasingly used for drafting purposes, a design activity which is now almost completely computerized in architectural offices. If the role of computer in architectural design remained merely as a drafting tool, its effect on architectural education would not be much different than that of pencils and drawing papers. However, beginning from the 1990s, developments in CAAD opened up new perspectives and challenged existing processes. Due to new visualization software, forms once were difficult to imagine became easy to produce and the "virtual" established as a legitimate architectural object. The next important change was the implementation of network technologies which gave rise to CSCW (Computer Supported Collaborative Work) and e-commerce. CSCW enabled collaboration of geographically distributed design professionals and formation of "virtual teams" (Tasli, 1999: 28-33). All of these events have affected traditional architectural design practices, although the impact was less far-reaching compared to large industries such as aerospace and automotive. The reason for this is probably the peculiar characteristics of the building industry. The building industry is more fragmented, project-specific and culturally diverse compared to the other industries (Pektas and Pultar, 2006). These factors hindered transformation of conventional practices in some extent, however, the incremental change is still in progress.

Architectural education has also been a part of these developments and has devised its own means of approaching CAAD. During the last decade, computing has been included in the curriculum of almost every architectural school. Many researches are being done on the subject and the debate on CAAD education proliferates through conferences of organizations such as ECAADE (Education and Research in Computer Aided Architectural Design in Europe), ACADIA (Association for Computer Aided Design in Architecture) and CAADRIA (Association for Computer Aided Architectural Design Research in Asia). Due to the developments briefly summarized above, CAAD education deserves further inquiry. In the following sections of this paper, several aspects of different approaches to CAAD education are discussed according to the proposed framework.

CONTENTS

A key topic for CAAD education is the content. "What" should be taught as CAAD, the theories, the methods, or the skills? Is CAAD an essential part of architectural thinking or just another skill that can be sought for competitiveness in the job market? Two opposite ends can be defined with respect to this question. Some view CAAD simply as a skill (Novitski, 1999) and others advocate that CAAD teaching should be related to the theories of architecture and/or should develop its own "digital design theory" (Oxman, 2006). Because of the wide diversity of the approaches to CAAD, categorizing the domain of digital design is a difficult task and of course, many interesting approaches are somewhere in between.

The conception of CAAD as a skill has been promoted mostly by practitioners and pragmatists due to the fact that CAAD has already become a driving force for architectural market. In a recent survey, practicing Turkish architects were asked to identify the factors that have been most influential in architectural practice within the last ten years. Following the developments in construction materials, computer technologies ranked second in a

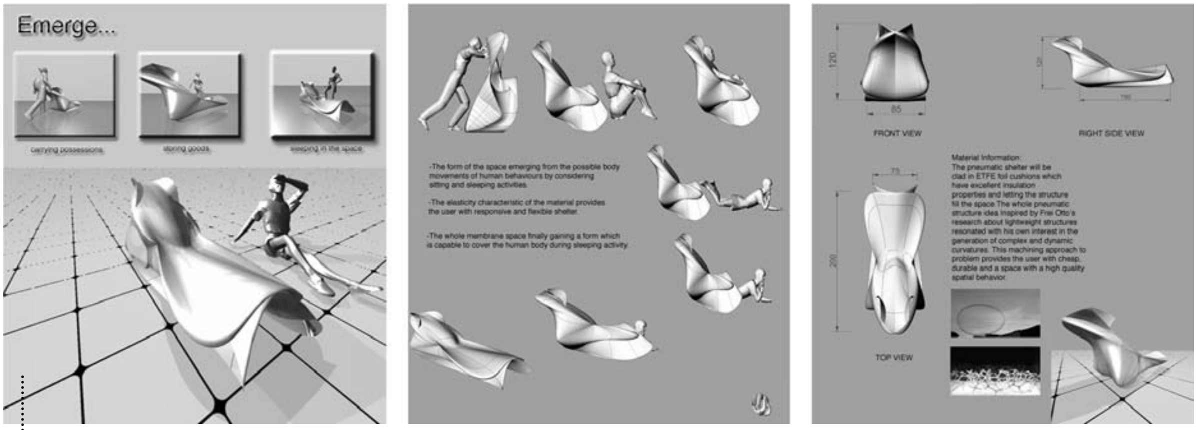

Fig 1. 3D modelling tools enable students to experiment with complex forms. "EMERGE" Participant for the international design competition entitled Designboom Social Awareness Award 2006, with the subject "Shelter in a Cart" for urban homeless. The figure shows a pneumatic structure with elastic material providing the user with a flexible shelter, not only for sitting and resting but also for sleeping, while the membrane finally covers the whole human body. (Designers: O. Ozkaya and O. Uludamar, Tutor: T. Sonkan)

number of factors. Moreover, the factors ranked third and fourth in the survey were also related to computers; namely, Internet and communication technologies and CAD technology (YEM, 2006). Under the demanding market conditions, architects seek for competence in the production of digital renderings, animations and construction documents while employing new graduates. Due to these developments and to the massive increase in architecture graduates, manual drafters with no architectural education have disappeared in recent years. They have been replaced by CAAD operators probably about half of whom are qualified architects (Stevens, 1997). Regarding these issues, schools are forced to shape the content of their CAAD curriculum to provide necessary skills and a competitive advantage for their graduates.

On the other hand, digital design is increasingly being conceived as a new form of design rather than merely conventional design conducted through digital media. The Non-Standard Architectures Exhibition at the Pompidou Centre in Paris (Migayrou and Mennan, 2003), catalyzed the emergence of the concept of non-standard and non-repetitive design as an antithesis of formal "complexity and contradiction" of post-modern architecture. Mitchell (2005) argues that the emerging architecture of the digital era is characterized by high levels of complexity which enables more sensitive and diverse response to the requirements of contextual aspects such as site, program and expressive intention than was generally possible within the framework of industrial modernism. The concept of a "non-standard" architecture, with its performative qualities, differentiation and dynamic evolution, have had profound effects on the contents of CAAD courses. An all-encompassing discussion of this paradigm is beyond the scope of this paper, but we may prospect that this argument will continue to inspire new theoretical content.

Considering the contents of individual CAAD courses, it seems that there is no limit. Computing, for modelling, simulation or communication, can be integrated with numerous topics. A CAAD course can focus on teaching how to use a specific computer program, or basics of digital design can be taught. Nowadays, students begin to architectural education with significant computer experience (Pektas and Demirbas, 2007). Office programs, e-mail and Internet have already become common knowledge and the need for computer literacy courses have diminished. Thus, this type of information can be offered only to the needed and CAAD education can cover more sophisticated issues. Oxman (2006) discusses that as digital media become more complex and more demanding with respect to knowledge of multiple types of applications, a new generation of digital design specialists is emerging. She coins the term "digerati"

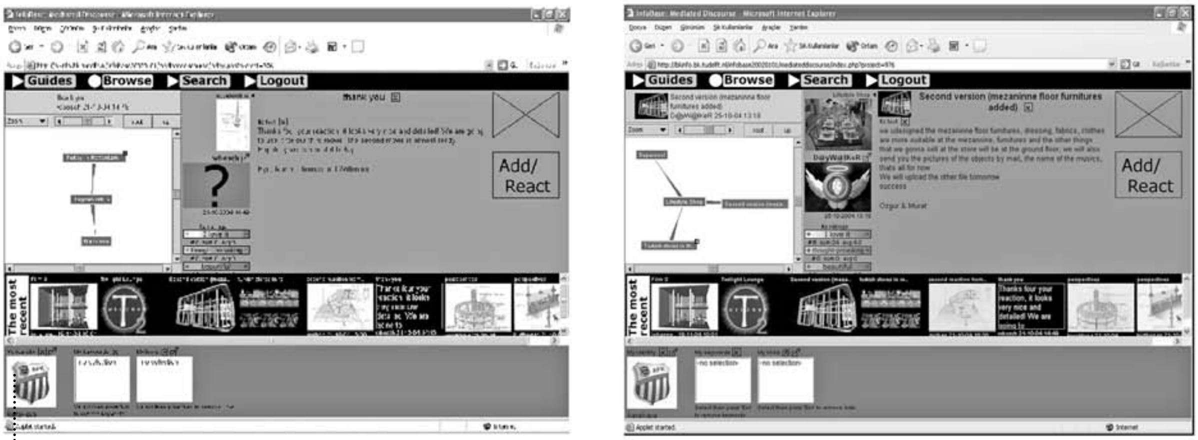

Fig 2. Web-based design studio as a rehearsal of professional collaboration between architects and interior designers. Snapshots from the communication in a virtual design studio conducted by Bilkent University, Turkey and Technical University of Delft, Netherlands during the Fall semester, 2004 (Moderator: F. Karakaya)

or digital literati corresponding to these new advanced digital systems designers. In order to educate "digerati," we suggest that since it is impossible -and also not necessary - to teach every CAAD package in the courses, only the core concepts should be introduced to students. Instead of burdening them with a mass of commands, students should be taught how to learn. The main aim of CAAD education in the digital age should be enabling students to understand the relevance of computing to their design process and to utilize it properly.

METHODOLOGY AND MEDIUM

Another important consideration about CAAD education is "how" it is delivered. In general, there are two main methods to teach CAAD in architectural schools: separate courses and the studio. There are also many hybrid applications and experimental practices. The studio is the main medium for the acquisition of design knowledge in architectural education. Therefore, it is assumed that it is the core and the other courses are complementary (Teymur, 1992: 34). Although some approaches claim that there is no need for CAAD courses since CAAD education should be a part of the design studio (Kalisperis and Pehlivanidou, 1998), separate CAAD courses are still the primary method of integrating computing in architectural curriculum. This situation is mostly due to the difficulties of fully digital studios. Their costs are high and studio instructors have to devote considerable time and energy to the subject. Furthermore, problems arise on what should be the weight of computer technology in the studio and whether or not it is feasible pedagogically. Moreover, when computers are introduced to the studio without initial CAAD training, inexperienced students tend to focus on technical difficulties rather than design concepts and they may be limited by their computer skills. Thus, it seems appropriate that basics of digital design should be initially taught in separate courses. After the initiation, the design studios should reinforce this training (Marx, 2000).

Separate CAAD courses may suffer from crowded classes and a limited time frame which often make it difficult to cover a great deal of information. Furthermore, since students often learn CAAD techniques passively in preliminary courses, they may become unapt at applying these techniques in new situations (Tasli, 2001a). In order to overcome these difficulties, we argue that CAAD education should be project-centric. Integrating CAAD with design projects enable students to explore the tools in the context in which they tend to be used. Moreover, in this way, computing is seen by the students as a part of the design process. Students are also more motivated to learn, because they are eager to produce a good project. Integration of CAAD and the design studio may not need to be revolutionary but small changes in educational programs, e.g. introduction of short design exercises

that simultaneously develop both computing and design skills and knowledge, may facilitate for learning-by-doing.

Besides studios and separate CAAD courses, there is another category of courses which utilize the Internet and network technologies to realize collaborative design learning. The courses in this group have different names in the literature such as Web-based studio, virtual design studio, and online studio. Within their great variability, the only common feature of the different web-supported studios is that some of the participants are remotely located from others. There are many motivations underlying such courses. First of all, they expose students to foreign environments and ideas of wider scope than is possible in traditional studios. They also help to teach collaborative work, facilitate for distance education, and promote peer learning. Al-Qawasmi (2006) discusses that influences of virtual design studios have been so profound since early 1990s that they have totally transformed traditional studio culture and pedagogy which had largely remained unchanged until that period.

An important ingredient of CAAD education is the software utilized. Commercial software used in CAAD teaching can be grouped into two: drafting-oriented software such as AutoCAD, ArchiCAD, CATIA, etc. and visualization-oriented software such as 3D Studio MAX, FormZ, Maya, Rhino, etc. Drafting-oriented software is widely used both in education and practice. Despite the developments in 3D modelling, 2D drawing still maintains its importance in CAAD education. In a recent survey of CAD instructors (Garcia et al., 2005), 2D drawing was considered as the most important aspect of CAD followed by dimensioning and layers, 3D modelling ranked fourth.

There is no doubt that 3D modelling and visualization software opened up new frontiers in students' imagination. Taking Gehry and Eisenman as their role-models, student designers are enthusiastic about experimenting with numerous complex forms within a limited time frame. The educational implications of these developments, however, should be carefully considered. On the one hand, increased number of design alternatives and the vision of a "non-standard" architecture are often viewed positively. On the other hand, it is observed that novice students fascinated by the representational capability of the tool are likely to ignore constructional and functional requirements of buildings in their projects. There is a growing amount of design instructors who complain about visually appealing but unbuildable student projects (Balfour, 2001).

Conventional CAAD software has already been integrated with architectural curricula, and it seems that the next step is parametric 3D modelling. Designing directly in 3D with intelligent objects has long been a dream of CAAD researchers (Tasli, 1999: 31-32). The elements in this type of modelling are "intelligent" in the sense that a wall is not merely two parallel lines but it "knows" that it is an architectural element which provides enclosure, bears loads and consists of openings for doors and windows. The 3D model becomes the source of all 2D drawings; sections and elevations can be automatically produced. Object-oriented programming enabled realization of these ideas in a great extent and toward the end of the 1990s most commercial CAD programs such as AutoCAD Architectural Desktop and AutoCAD Revit offered parametric 3D modelling (Autodesk, 2006). Some proponents of 3D modelling claimed that this technology will cause a revolutionary change in design processes of architects and classical plan-elevation-section will become obsolete (Novitski, 1998). However, this has not happened in reality not only due to the fact that changes in customary processes are difficult and incremental but also that those representations are insightful and useful abstractions of design ideas (Johnson, 2002). It seems that the new instance of 3D models have been embraced by architects not as a substitute of the conventional drawings but as a means to produce them consistently and efficiently. Whereas, in the educational practice, computer models are still viewed in traditional modelling terms as non-parametric, non-mutantable, static objects rather than object-oriented, dynamically simulated, virtual objects. Fortunately, developments in parametric 3D modelling software seem promising in order to overcome this problem (Tasli, 2001b).

STAFF AND MANAGEMENT

Another important question regarding CAAD education is: "who" should be responsible for teaching CAAD? A decade ago, there was a lack of qualified full-time CAAD instructors in architectural schools. In 1997, a worldwide survey revealed that 55% of CAAD instructors were part-time (Qaqish and Hanna, 1997). Moreover, the studies consistently reported a tension between traditional and digital tools in the studios (Hanna and Barber, 2001). Due to the growing interest of academics in CAAD, a young generation of CAAD instructors who are both educators and researchers has emerged in the last decade, however, the reluctance in the studios seem to be persisted (Pektas and Erkip, 2006). Possible reasons for this reluctance are lack of proficiency of the instructors in computers (Erkip et al., 1997), focusing only on the "conceptual" phase of architectural design process and seeing the existing CAAD tools as merely drafting rather than design tools (Hanna and Barber, 2001), fearing that supporting CAAD in design education will lead to the loss of hand drawing skills in time (Shu, 2000), conservatism and caricaturizing the people who specialize in computers as "nerds" (Tweed, 2001). On the other hand, some instructors may be disinclined to use computers in education, since they perceive some shortcomings of the existing CAAD tools such as providing insufficient support at early design stages (Pektas and Erkip, 2006).

Integrating CAAD with design teaching necessitates collaboration of the faculty. Studio instructors, not necessarily being experts on the subject, should understand the potentials and limitations of the digital media. Team teaching may facilitate for this purpose. In this method, either a faculty member teaches both a CAAD class and a design studio at the same year level, or if this is not possible, CAAD instructors can contribute to studio critics just like environmental performance and construction tutors do. Both of these necessitate their being competent both in CAAD and design and devoting considerable effort to the task. Parallel exercises are another approach to integrate CAAD courses with the studio. The course sequence is an important consideration in that respect; introducing different levels of computing in the curriculum in step with the overall level of education may provide satisfactory results (Tasli, 2001a).

ISSUES REGARDING DIFFERENT KNOWLEDGE LEVELS

In order to present a systematic perspective to CAAD education, its different aspects should also be analyzed in sociological, ideological, epistemological and pedagogical levels. Sociological level corresponds to sociological definition of architectural education, its problems and contents. Although it has been known that individual differences of learners such as computer attitudes, learning styles/preferences, personality type and gender are influential in determining the success of efforts to integrate technology with education, most of the studies on CAAD (as well as the design institutions themselves) have focused merely on the technical aspects. Socio-cultural and behavioural issues of CAAD education have often been ignored (Pektas and Erkip, 2006). Hence, we believe that architectural education is urgently in need of researches on such aspects of CAAD.

Ideological level consists of relationships between architectural profession and its education. Architectural education, contributing to the reproduction of architectural labour force, is profession-oriented unlike discipline-oriented science education (Teymur, 1994). Then, it is not surprising that there have always been disagreements between the practicing architects and the academia on the content and the methods of education. The different value systems of both parties manifest themselves in their approaches to CAAD teaching as well. Practitioners sometimes express disappointment about how students are trained for the profession and force schools to enhance their CAAD teaching (Novitski, 1999). While architectural practice tends to use CAAD in conventional terms, mostly for efficiency in production; in schools, approaches to CAAD span a wide range between hesitations toward utilization to advance uses of computers for augmenting architectural imagination. Unlike most architectural offices depend only on computerized drafting after the preliminary design stage; these

two media tend to exist simultaneously in the schools.

Epistemological level is related to content and utilization of knowledge and its interdisciplinary aspects. Three main potentials of CAAD in this respect may be addressed, namely, systematization, different representations of design knowledge and collaboration (Tasli, 2001a). Architectural practice is often conducted through normative processes and intuition. Similarly, in architectural education, an architect is often portrayed as a "black box" that produces designs mysteriously. However, in order to work with a computer one has to be clear about the task, be it a process or a geometrical description. This may enable students to be aware of the steps or the procedures followed to complete a design. The possibility of different representations of design knowledge -in the form of visualizations, simulations, rules, or case studies- is another potential of CAAD in epistemological level. In the studio tradition, a studio instructor plays the role of the master who demonstrates how to design by a kind of thinking by doing which Schön called "reflection-in-action." (1985). In this practice, students' performance criteria for design are often based on the approval from the master. However, computers allow several representations of performance criteria (lighting, acoustics, structural strength, etc.) as well as the four-dimensional experience of building aesthetics, which can be easily accessed, or directly attached to the building model. In this way, students' own creativity can be more effectively merged with the theories of the discipline. Finally, establishing ways of sharing in design education promotes students' understanding of how different values exist simultaneously.

Pedagogical level involves learning theories, techniques and course design. Some of the pedagogical aspects of CAAD education are discussed in the previous sections. However, like its socio-cultural aspects, pedagogical aspects of CAAD are also rarely discussed in the literature. It seems that the rapid implementation of computers in design curricula has caught schools unprepared to develop new pedagogical methods adapted for a digital practice. Hence, systematic approaches and experimental research on the curriculum design and teaching methods are much needed.

CONCLUSION

In this paper, a framework for addressing most of the important aspects of CAAD education based on Teymur's system is suggested. Throughout the paper, it is emphasized that after many years of experimenting, computerized practices are no longer admired only for the sake of the tool, but their relevance to architecture education is questioned. Relations between digital design and architectural design theories, or prospective contents of a "digital design theory" are interesting inquiries toward a theoretical discourse of digital design. As educators and researchers, we may be inspired by this new agenda.

In schools, computers and visualization software are creating interesting opportunities for design experimentation. However, it is increasingly observed that, such experimentation is not well-connected to building real-life projects. Parametric 3D modelling and dynamic simulation in virtual environments enable students to evaluate future performances of designs and developments in this area seem promising for bridging the gap between the fantasies of digital world and the materiality of the real-life. As costs of such systems decrease and their compatibility with modelling software increase, more educators will be able to utilize them and we may have a better understanding of how to teach students to design digitally.

CAAD education research has already established with its own knowledge base and research methods. However, most of the studies on the subject have traditionally focused on technical/empirical aspects of CAAD education (such as development of new tools and description of experimental CAAD courses). There are also relatively few theoretical studies basically dealing with the analysis and formal modelling of design processes and cognitive activities of designing such as the works of Cross (2000) and Lawson (1997). All of these approaches are valuable and produced significant results, but, the framework used in this paper revealed that the wide context of CAAD education has not been systematically analyzed, understood and exploited yet. Hence, we suggest that CAAD education community should focus more on the socio-cultural and pedagogical aspects of CAAD to

better respond to the demands of the profession and the society at large. We hope that the framework proposed in this paper will facilitate for further studies.

REFERENCES

AL-QAWASMI, J. 2006, "Transformations in Design Education: The Paperless Studio and the Virtual Design Studio," *Open House International,* 31(3), pp. 95-102.

AKIN, O. 1986, *Psychology of Architectural Design,* Pion, London, UK.

AUTODESK 2006, *Autodesk Revit for AutoCAD Users,* Available at: http://images.autodesk.com/adsk/files/Revit_for_AutoCAD_Users.pdf

BALFOUR, A. 2001, "Architecture and Electronic Media," Journal of Architectural Education, 54(4), pp. 268-271.

CROSS, N. 2000, *Engineering Design Methods: Strategies for Product Design,* John Wiley and Sons, Chichester, UK.

ERKIP, F., DEMIRKAN, H. and PULTAR, M. 1997, "Knowledge Acquisition for Design Education," *Proceedings of the International Conference on Design and Technology Educational Research and Curriculum Development,* Loughborough University, Loughborough, UK, pp. 126-132.

GARCIA, R. R., SANTOS, R. G., QUIROS, J. S., and PENIN, P. I. A. 2005, "Present State of CAD Teaching in Spanish Universities," *Computers and Education,* 44, pp. 201-215.

HANNA, R. and BARBER, T. 2001, "An Inquiry into Computers in Design: Attitudes before - Attitudes after," *Design Studies,* 13, pp. 255-281.

JOHNSON, S. 2002, "The Slow and Incremental "Revolution,"" *Journal of Architectural Education,* 56(2), pp. 49-54.

KALISPERIS, L. N. and PEHLIVANIDOU, A. 1998, "Architectural Design Studio: Digital and Traditional," *Computers in Design Studio Teaching: Proceedings of the EAAE-ECAADE Workshop,* Leuven Dept. of Architecture, Leuven, Belgium, pp. 73-81.

LAWSON, B. 1997, *How Designers Think,* Architectural Press, London, UK.

LAWTON, D., GORDON, P., Ing, M., GIBBY, B., PRING, R. and MOORE, T. 1978, *Theory and Practice of Curriculum Studies,* Routledge & Kegan Paul, London and New York.

MARX, J. 2000, "A Proposal for Alternative Methods for Teaching Digital Design," *Automation in Construction,* 9, pp. 19-35.

MIGAYROU F. and MENNAN, Z. 2003, *Non Standard Architectures,* Editions du Centre Pompidou, Paris.

MITCHELL, W. 2005, "Constructing Complexity," *Proceedings of the Tenth International Conference on Computer Aided Design Futures,* Vienna, Austria, pp. 41-50.

MITCHELL, W. 1994, "Three Paradigms for Computer Aided Design," *Knowledge Based Computer Aided Architectural Design,* G. Carrara and Y. Kalay (Eds.), Elsevier, Amsterdam, pp. 379-89.

NOVITSKI, B. J. 1999, "The Computer Education Received by Today's Architecture Students may not Provide them with the Skills Sought by Employers," *Architectural Record,* 187(4), pp. 39-42.

NOVITSKI, B. J. 1998, "An Architectural Awakening," *Computer Graphics World,* 21(6), pp. 22-40.

OXMAN, R. 2006, "Theory and Design in the First Digital Age," *Design Studies,* 27, pp. 229-265.

PEKTAS, S. T. and DEMIRBAS, O. O. 2007, *Computer Attitudes, Learning Styles and Computer Experiences of Interior Architecture Undergraduates,* Unpublished Research Report, Bilkent University, Turkey.

PEKTAS, S. T. and ERKIP, F. 2006, "Attitudes of Design Students toward Computer Usage in Design," *International Journal of Technology and Design Education,* 16(1), pp. 79-95.

PEKTAS, S. T. and PULTAR, M. 2006, "Modelling Detailed Information Flows in Building Design with the Parameter-based Design Structure Matrix," *Design Studies,* 27, pp. 99-122.

QAQISH, R. and HANNA, R. A. 1997, "World-wide Questionnaire Survey on the Use of Computers," *Architectural Education, Architectural Design: Proceedings of the 15th ECAADE Conference,* Available at: http://info.tuwien.ac.at/ecaade/proc/qaqish/qaqish.htm

SAGUN, A., DEMIRKAN, H. and GOKTEPE, M., 2001, "A Framework for the Design Studio in Web-based Education," *Journal of Art and Design Education,* 20(3), pp. 332-342.

SALAMA, A. M. 2006, "Learning from the Environment: Evaluation Research and Experience Based Architectural Pedagogy," *CEBE Transactions,* 3(1), pp. 64-83.

SCHÖN, D. 1985, *The Design Studio: An Exploration of its Traditions and Potentials,* RIBA, London, UK.

SHU, E. H. A. 2000, "Touch versus Tech: Hand-drawn or Computer Rendered Techniques," *Architectural Record,* 188(2), pp. 170-173.

STEVENS, G. 1997, "Reflections of an Apostate CAD Teacher," *Journal of Architectural Education,* 51(1), pp. 78-80.

TASLI, S. 1999, *Dynamic Simulation in Virtual Environments as an Evaluation Tool for Architectural Design,* Unpublished Dissertation, Bilkent University, Turkey.

TASLI, S. 2001a, "Bridging the Gap between Theory and Practice in Architectural Education: The Case of CAAD Teaching," *Re-integrating Theory and Design in Architectural Education: Proceedings of the 19th European Association for Architectural Education (EAAE) International Conference,* EAAE, Leuven, Belgium, pp. 203-209.

TASLI, S. 2001b, "What does Computer Aided Design Offer for Producing Livable Buildings in the 21st Century?" *Proceedings of the Livable Environments and Architecture International Congress (LIVENARCH 2001),* KTU, Trabzon, Turkey, pp. 278-282.

TEYMUR, N. 2001, 4x4 - *Towards a Working Theory of Architectural Education*, Presented at AEE 2001 Conference, Available at: http://cebe.cf.ac.uk/aee/pdfs/teymur1.pdf

TEYMUR, N. 1997, *Bir Mimarlik Kuramina Dogru (Towards a Theory of Architecture),* Mimarlik Egitimi Ve, TMMOB, Ankara, Turkey, pp. 5-43.

TEYMUR, N. 1994, "Initiation Myths and Curricular Fallacies," *Beginnings in Architectural Education,* ACSA/EAAE, NY, pp. 89-90.

TEYMUR, N. 1992, *Architectural Education: Issues in Educational Practice and Policy*, ?estion (sic) Press, London.

TWEED, C. 2001, "The Social Context of CAAD in Practice," *Automation in Construction,* 10, pp. 617-629.

UIA (The International Union of Architects) 2002, *UIA and Architectural Education Reflections and Recommendations,* Text adopted by the 2002 UIA Assembly, Berlin, Available at: www.uia-architectes.org/image/PDF/Reflex_eng.pdf

Yapi Endustri Merkezi (YEM) 2006, *Serbest Mimarlik Burolari Raporu 2005,* Yapi Endustri Merkezi, Istanbul, Turkey.

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VIRTUALIZATION OF ARCHITECTURAL DESIGN EDUCATION IN THE ARAB REGION: Potential and Cultural Implications

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Abstract

The influence of digital media and information technology on architectural design education and practice is increasingly evident. There has been an astonishing shift in the way architecture is being taught and produced. Networked virtual design environments such as the virtual design studio (VDS) have been introduced in many architectural schools as new ways of teaching and learning design. Applying virtual design education in developing countries such as the Arab states brings with it various opportunities and challenges. As a new phenomenon, little research has been done to study the cultural implications of the new virtual design environments (VDE). This paper examines the new paradigm of teaching and learning design virtually and the possible cultural implications of its implementation in developing countries such as the Arab world.

Keywords: *Virtual Design Education, Virtual Design Studio, Virtualization of Education, Architectural Education.*

1. INTRODUCTION

Ever-advancing digital technologies have greatly changed the way architecture is being taught and produced. Over the last decade or so, virtual collaboration environments have become very popular in academia and the profession. Virtual learning environments such as the virtual design studio (VDS) have been introduced in many architectural schools worldwide to prepare students for future distributed working environments. Using communication and collaboration tools, a virtual design environment (VDE) allows geographically dispersed students and instructors to interact, form teams, conduct virtual reviews, and participate in design critique via desktop computers.

Implementing virtual design education in developing countries, such as the Arab region, brings with it various opportunities and challenges. Previous research revealed a need to examine the new learning environment and its appropriateness for implementation in the developing countries (Strojan and Mullins 2002). This paper examines the potential of implementing virtual design education in the Arab region and its cultural implications.

2. VIRTUAL DESIGN EDUCATION

Recent advances in computer networks and communication have enabled multiple designers to collaborate using a virtual design environment (VDE). A VDE is a computer-mediated environment that enables students and designers to interact and design via their computers. The users' location becomes irrelevant because the virtual design studio is an electronically distributed workplace, and users enter this virtual place by connecting to the Internet.

Over the last decade or so, a number of architectural schools in the United States, Europe, and Asia have taken advantage of the unique capabilities of the Internet to conduct what has been called the virtual design studio (VDS). Virtual design studios can range from simply using e-mail for project communication to a collaborative VDE. In these studios, students from geographically separated educational institutions work together using VDE as if they were part of one design studio. In these experimental VDSs, individual communication and collaboration technologies were assembled and customized to provide an integrated VDE. These collaboration technologies can be broadly classified into two groups: asynchronous tools and syn-

chronous tools.

Asynchronous tools are computer-mediated environments that enable participants to interact and share information asynchronously by storing and retrieving data from a shared location. These tools include File Transfer Protocol (FTP), e-mail, shared databases, discussion forums, and the World Wide Web (WWW). These tools enable students and instructors to publish, retrieve, and exchange graphics, images, textual comments and attachments of sketches and drawings. As such they support asynchronous reflections, group discussions and brainstorming, and the exchange of ideas and representations.

Synchronous tools are computer-mediated environments that allow a geographically dispersed group of users to interact simultaneously through their desktop workstations. These include tools such as text-based chat, digital whiteboard, audio and video conference, and application sharing. These tools allow users to engage in live interaction using communication channels while simultaneously working on a shared 3D model or a raster image.

A special version of the virtual design studio was based on compressed videoconferencing technologies (Vasquez de Velasco, 1997, 1998). In the Mex-Tex VDS (1996-1998), a variety of videoconferencing technologies were used in addition to Internet-based technologies. These technologies included Electronic White-Board, where participants can interact in real-time over the same drawing making use of a bitmap editor; Electronic Project Presentations, where a computer window is transmitted to remote parties; Smart-Boarding, where the image transmitted is a room view showing the student standing in front of a large-format presentation program; or Video Feedback, where the image of a student presenting a project is projected in one-to-one scale at the remote location.

In a recent VDS initiative, an immersed virtual reality environment was used as a VDE. In VeDS 2001 (Virtual Environment Design Studio) conducted between the University of Hong Kong (HKU) and Bauhaus University at Weimar (BUW), the participants used Kaiser Proview HMD, with other Internet-based communication tools (Schnabel et. al. 2001). The designer wore a virtual reality headset and designed by gesturing while holding a magnetically- tracked stylus. The gestures were converted by VRAM (Virtual Reality Architectural Modeler) software into 3D forms.

In many respects the virtual design studio experiments are breaking new ground in the teaching of architecture. However, reports on the last decade's VDSs, as presented in the proceedings of associations such as ACADIA, eCAADe, and CAADRIA, pointed out that limited bandwidth and other limitations of current collaboration technology have negatively impacted design knowledge delivery (Cheng et al. 1994, Wojtowicz 1995, Tan & Teh 1995, Kolarevic et al. 1998, Dave & Danahy 1998, Donath ET. AL. 1999). Heavily used networks may result in slow or jerky interactive digital models, or in the loss of audio or video signals, or when things go bad, both (Al-Qawasmi, 1999). As a new phenomenon, little research has been done to study the new distributed teaching environments and how they affect design education and design process.

3. IMPLEMENTING VIRTUAL DESIGN EDUCATION IN THE ARAB WORLD: PROSPECTS AND CULTURAL IMPLICATIONS

In order to catch up with architectural schools in developed countries, architectural schools in developing countries are working hard to build up their information technology skills and equipment. Even though the application and use of information technology in architectural education in Arab states has been underutilized, over the past few years there has been tremendous growth in the use of information technology. Many architectural schools in the Arab world, for instance, have adopted computers in architectural education and integrated them in their curriculum. Almost all architectural schools have introduced computers and CAAD courses in their curriculum. Some schools went further and have integrated digital media in certain design studios in the form of a paperless studio or e-studio (Al-Qawasmi 2005). Some schools, such as Jordan University of Science and Technology, King Fahd University for Petroleum and Minerals (KFUPM), and King Abdel Aziz University (KAAU),

have, completely or partially, replaced traditional drawing boards with tables for computers. Other schools, such as KFUPM and University of United Arab Emirates (UAEU), have introduced advanced technologies such as virtual reality in teaching and learning design. Thus, digital media seem to have become integral parts of architectural education and professional practice in the region. Unfortunately, after more than a decade of conducting virtual design studios, architectural schools in the region did not consider yet the new virtual learning environments or utilize them in architectural education and practice. One reason for this phenomenon is associating networked design studios with globalized flows of information and culture that are thought to fragment people's ties with the "local" and promote hybridity and transcultural forms.

Teaching and learning design virtually is based on the heavy use of telecomputing and network technologies, the very technologies that facilitate globalization. As such virtual design education is often seen as a double-edged tool that brings opportunities and challenges, advantages and disadvantages. How to capitalize on advantages and avoid disadvantages in the tidal wave of globalization depends on formulating proper policies and strategies. On the basis of previous experiences in conducting VDS, there is a need to develop and implement an appropriate model of virtual design education that can maximize opportunities and minimize challenges for developing countries (Strojan & Mullins 2002). Virtual design education needs to be carefully analyzed and considered, but as a new environment for education it is as vital to developing countries as it is to developed countries. Below I will discuss the possible cultural implication of implementing virtual design education across the Arab states.

3.1. REGIONAL COLLABORATION VS. GLOBAL DESIGN CULTURE

Contemporary architectural education and practice in the Arab region is dominated by a global culture of design. Most, if not all, architectural schools in the region are based on Western architectural education models. Architecture textbooks and professional magazines are of Western origin. International architectural styles and trends are distributed all over the region and the world through international magazines, the Internet, and other media. A look at modern architectural products in the region illuminates the diasporic hybridity of architectural forms that echoes the dominant design culture. The global culture of design and the mobility of transcultural forms introduce new diasporic associations, identifications, and resistances and incite new appeals and desires while at the same time commodifying and sustaining the dominant Western/Anglo culture.

In contrast to this flow of global design culture - at both the pedagogical and professional levels - there is an absence of pan-Arab architectural dialogue, which has resulted in a complete ignorance of cultural and educational traditions of the region. Students, instructors and professionals in Jordan or Saudi Arabia, for example, know very little about local practices and architectural heritages of other Arab countries such as Tunisia or Lebanon. In an era dominated by global design culture, regional connectivity and collaboration on the architectural level must be strengthened even further. Otherwise the hegemonic globalization culture will prevail and the people of the region will have less and less control of the sociopolitical space they inhibit.

Kenneth Frampton (1996, p. 471) argues that promoting regional architecture "depends, by definition, on a connection between the political consciousness of a society and the profession." While it is difficult to achieve connection among various communities in the traditional model of architectural design education, virtual design education can enable translocal interactions and connections across the Arab region. For example, it can open architectural schools to other architectural schools nationally and regionally. It can be used as a tool for regional collaboration between architectural schools or to form multidisciplinary teams from students in different departments such as architecture, planning, landscape architecture, and construction.

Forming virtual teams of architecture and urban planning students to work on an urban conservation project, for example, may have several advantages, not least of which are enhanced learning about regional experiences in urban conservation

and introducing students to new forms of practicing urban conservation. A regional VDS can also provide students with continuous access to distributed digital libraries of modern and historical buildings from the region. Furthermore, experts can also be virtually brought into the studio to provide specialized information and consultations. In this way, virtual learning environments will provide opportunities to exchange regional experiences and build partnerships among concerned individuals and institutions: students, instructors, professionals, and academic and professional institutions. As such, virtual learning environments can be instrumental in promoting and infusing both national architectural identities and regional identifications and associations. Promoting and strengthening regional communication and cooperation opens up possibilities to build indigenous capacity that helps reduce Arab countries' dependence on the architectural knowledge and services of the developed world and help them apply new technologies to solving complex local problems.

From another perspective, one may argue that architecture is a cultural phenomenon and, as such, should be understood within its cultural and social context. Exposing students to regional built environments, ideas, and practices enhances their understanding of regional architecture. To achieve such cultural interchange, many international architectural schools have invested heavily in study abroad and other off-campus programs to expose students to foreign environments (Vasquez de Velasco 1998). Virtual learning environments can support and augment the current practices of such programs in several ways. For instance, students can conduct virtual contacts with other regional (sub)cultures instead of moving physically there. This minimizes the logistics needed for physical mobility and thus may increase the number of participants in these programs. Previous research pointed out that virtual contact with other cultures is a powerful resource for exposing students to other cultures and practices and for providing a multicultural dimension to undergraduate programs (Vasquez de Velasco 1998). This research also showed that virtual contact promotes real contact rather than discourages it.

The above scenarios and others show how the appropriate implementation of virtual learning environments that span geographic regions can be, as argued by Castells (1997), instrumental in developing and strengthen countertrends and regional resistance against globalization forces and culture of compliance.

3.2. VIRTUAL LOCALITIES VS. DELOCALIZATION

Networking technologies such as the Internet are perceived prominently as technologies of delocalization. They are associated with globalized flows of information and culture that promote universal values and contribute to the blurring of national boundaries. Here, I argue that networked technologies, if used appropriately, can promote locality by strengthening ties with the "local".

Virtual design education has the potential to make the various stakeholders in architecture education and practice more local, in the sense that they are rooted in their problems, in their communities, and in their identities. For example, virtual design education has the ability to engage the outside world in the educational process, and thus open architectural education to societies and to the real world. In contrast to hypothetical architectural projects being used in traditional design education, the virtual design studio can link design education to a real world with budget, clients, resources, and material. Instructors can, for instance, propose design projects with real sites and real clients. Students can use synchronous and asynchronous collaboration tools to contact and interact with the client from their studio or wherever they may be. Actual projects in the region can be used as case studies to demonstrate different building traditions and building types. From this perspective, the virtual design environments encourage associations and connections that span geographic regions, but are grounded in concrete places, practices and material relations.

Furthermore, virtual design education can also open architectural schools to local and remote communities. Architectural schools can establish a virtual studio to serve as a center for community-based projects. The virtual studio minimizes the

efforts and logistics needed to work on community-based projects. In such a studio, students can work and interact with multidisciplinary teams that may include community members, planners, city governments, conservation specialists, and other entities involved in design and construction. In this context, a virtual studio will enable architectural schools to shape distinct educational agendas particular to their local environments as well as to remote regional environments. The VDS, thus, has the potential to make us more local, in the sense that students, instructors, and educational institutions are rooted in their problems, in their communities, in their groups, and in their identities.

The above mentioned scenarios and others show how locality can be promoted not only through physical contacts and geographically rooted places but also though virtual contacts and "virtual localities". Engagement through a VDE can be seen as an interactive and communicative process that produces and condenses associations across the region. These virtual affiliations/associations represent a new form of locality that can be called "virtual localities". Thus, the flows of electronic information that are thought to fragment our ties to the local seem to promote new local/regional associations.

3.3. CULTURAL EXCHANGE VS. CULTURAL HYBRIDITY

Castells (1997) argues that cross-cultural networks do more than facilitating collaboration, sharing of information, and virtual organization of activities. According to Castells these networks "are actual producers, and distributors, of cultural codes". Contemporary cultural theoreticians point out that the cultural exchange occurring during the collaboration between different cultures provides fertile ground for human discourse. Such statement is true only when we talk about a balanced cultural exchange. In the absence of balanced and fair cultural relations, the exchange of cultural codes across a networked virtual design system may result in the opposite; that is, domination of global values and practices on the cost of local practices. For example, the cultural exchange in a virtual design studio conducted between the US and a developing country may result in cultural challenges for students located in the developing country. Under such unbalanced cultural exchange the weak culture is vulnerable to be transformed into a hybrid culture or what Bhabha calls the "third space of enunciation" (Bhabha 1994, p. 37), a space where aspirations to fully acknowledge national culture can never be realized.

Cultural hybridity theory recognizes that all cultural relations are ambivalent, subversive, transgressive, and hybrid. According to Bhabha (1990) the notion of hybridity is not intended to demarcate a new and entirely of-itself identity or cultural form. In Bhabha's view (1990, p. 211) the hybrid is a state that does not conform to one thing or another; it is rendered an "other" from both cultures. Cultural hybridity, thus, does "not comprise of two original moments from which the third emerges", but gestures toward an ambivalent "third space" of cultural production and reproduction.

A look at contemporary architectural products in the region illustrates the diasporic hybridity of architectural forms. Such hybrid architecture is a reflection of the absence of balance and equality in contemporary architectural and cultural exchange. Although the manifestation of internationalization and globalization is very strong in academia and the profession, however, according to Stuart Hall (1990), the effects of diasporic hybridity are not final or inevitable but can be turned around to make for new forms of resistance and contestation. In the architectural domain, this turnaround can be achieved through proactive actions, among which are providing a wider network of translocal and transregional interconnections that enable connectivity and openness to local and regional (sub)cultures.

In contrast, conducting a pan Arab virtual design studio (PA-VDS) provides a two-way cultural exchange that results in cultural benefits in terms of richness and diversity. Architectural and cultural heritage of the Arab region represent a multifaceted culture. Establishing VDS between Arab architectural schools will provide opportunities for balanced cultural exchange and translocal interactions, and thus provide a restoration to the norm. Furthermore, as producer and transmitter of cultur-

al codes between combatable (sub)cultures, a PA-VDS will be instrumental in developing and strengthening regional movements of social and cultural resistance such as that proposed by Kennth Frampton. According to Frampton (1996, p. 471) "those recent regional 'schools' whose primary aim has been to represent and serve, in a critical sense, the limited constituencies in which they are grounded" are important tools in promoting critical regionalism. He states that those schools tend to promote "an anti-centrist sentiment - an aspiration at least to some form of cultural, economic and political independence".

3.4. VIRTUAL DESIGN EDUCATION AND THE MAKING OF ARCHITECTURAL IDENTITY

The search for a national identity has always been a crucial, yet difficult, endeavor for all nations. For mutlicultural nations such as the Arab nation the effort is even more so. It is argued that dealing with national architectural identity in the twenty-first century will be more complex than ever before. Manuel Castells (1997) pointed out that the networked societies are witnessing a powerful surge in searching for and expressions of collective identity. According to Castells "In a world of global flows of wealth, power, and images, the search for identity - collective or individual, ascribed or constructed - becomes the fundamental source of social meaning."

The dynamisms of identity making have changed via the emergence of the information society. Unfortunately, in the architectural domain, the architectural identity discourse is still a retrospective one. The tendency is toward analyzing architectural identity and describing or characterizing its historical roots, elements, etc. The mechanisms, tools, actors, and media involved in the process are rarely considered. More rigorous research is needed to examine possible cultural implications of a virtual learning environment such as the VDS, and how it may affect the making of architectural identity. However, it will be a beneficial exercise to reflect here upon how networked virtual design education may affect different types of architectural identity. The section below will examine how architectural identity is produced, transformed and transmitted through virtual design environments. Particularly, it focuses on how new virtual learning environments affect the making of architectural identity.

Natural identity. It may be difficult to define a natural architectural identity. However, one can refer here to two relevant notions: the "spirit of the times" used by the modernist and the "spirit of the place" used by the postmodernist. The spirit of the times concept refers to the fact that architecture should respond to the available sciences, technologies, manufacturing means, and economic considerations of a particular time. The spirit of place concept refers to the fact that architecture should respond to the geographical and climatic considerations of the site and the cultural values of a particular society. To reflect a natural identity, architecture should respond to both notions: spirit of the times and/or the spirit of the place.

Implementing virtual design education in the Arab region provides opportunities to promote natural architectural identity through democratization of design education, openness to local and remote communities and openness to regional (sub)cultures and their practices and traditions. I would argue that among the preconditions for promoting natural regional architectural identity is an efficient forward-looking education system. Nobody contests the notion that promoting a national or regional architectural identity begins with attitudes, skills and commitments first learned and encountered in professional school.

Constructed identity. Contemporary cultural theoreticians point out that cultural identity has often been constructed by various cultural, social, and political institutions. When those institutions impose their political and social preferences, the result is a constructed architectural identity. From a postmodern perspective, buildings and architectural identities are mere constructions of discourses and practices. Castells (1997, p. 7) pointed out that "from a sociological perspective, all identities are constructed". Michel Foucault (1972, 1988) has discussed the discontinuity in history. According to Foucault, the history of knowledge is a construction dominated by social and cultural institutions. Similar to history, tradition, or language, buildings

and cities and their architectural identity are also constructions. For example, a look at the recent past of the region - the Ottoman period - shows how the political institutions of most modern Arab national states offset or ignore this history. It is not that it does not exist; it has been censored.

Forced identity. A forced architectural identity usually is driven by market opportunities, business agendas, and pure economic concerns. Forced architectural identity sponsors include, among others, governmental agencies and insensitive developers that fail to consider people's social and cultural values.

Implementing pan-Arab virtual design education opens up possibilities to enhance the identifications of local and regional architectural identities. It also can create opportunities to counteract and deconstruct all illegitimate forms of architecture and offset the absence of the natural identity resulted from imposing constructed and forced identities.

Global identity. Global architectural identity reflects a common information-age culture. It is the result of the globalization of cultural values, uniform architectural styles, and stereotypical patterns of space and form. It is a kind of internationalized, innovative architecture transcending local conventions and constraints. Global architectural identity places a premium on systematization, flexibility, interchangeability, and new technologies and materials. It is expected that implementing a pan-Arab virtual design education will provide a mechanism to mobilize the various architectural institutions in the region and extend more power to them and communities in formulating and defining local and regional culture. This will thus promote localism and regionalism as a reaction to uniform architectural styles and globalization of cultural values.

3.5. ISSUES OF ACCULTURATION AND REPRESENTATION

Acculturation (or enculturation) is the process whereby a specific cultural group teaches an individual by repetition its accepted norms and values. It is the process by which individuals acquire the knowledge, skills, habits, attitudes, and values that enable them to become functioning members of the group. Thus, it seems appropriate to examine the social and cultural implications for teaching/learning in a virtual design environment, a critical issue for developing countries, such as Arab states. Here we will analyze two issues: 1) the ability of a VDE to capture and communicate cultural aspects of architecture, and 2) VDE as a locus of acculturation.

3.5.1. Representing and Communicating Cultural Meanings

Architecture has been commonly acknowledged as a physical entity and a multifaceted cultural phenomenon. It is often argued that associations, underlying meanings and other nonphysical aspects of a building are as important as its physical aspects, if not more. Although there are several positions concerning the issue of meaning in architecture, there is an agreement that "any artifact or environment carries a number of meanings simultaneously" (Lang 1987, p. 95). In other words, architecture communicates a varied set of meanings, regardless of the original intentions of the designer.

It is often argued that digital media tend to create and compile value-free elements and thus are unable to communicate cultural and symbolic meanings (Piotrowski 1998; Al-Qawasmi 2005). The argument is that CAAD systems and digital technology as used in various VDEs, transform buildings into elements of global exchange and, in this way, support commodification and globalization of architectural products and values, and thus hinder the communication of local traditions.

The above criticism is a valid one. However, it should be emphasized that this criticism is not limited to digital media only, but applies to all other forms of representation. As architecture has and communicates a variety of meanings, one cannot argue that representation alone can capture and communicate all these meanings. Visual images and representation do not provide clear-cut identity and identification. From a deconstruction perspective visual representations and readings are an effect of standpoint, belief and value, and support multiple and often contradictory understandings. Furthermore, research points out that the value system and the past experience of the observer inter-

rupts and interacts with his perception to give new meanings (Lang 1987). In this way, it is expected that a terrain of meanings and identities will arise from a building representation, regardless of the original intentions. Therefore digital technology used in the various VDEs cannot objectively communicate the range of meanings associated with architecture or its significance for communities. Multiple and contradicting understandings of these images/representations are expected.

However, I would argue that, compared to other poor, unidirectional and single channel media available on the Internet, media richness of a virtual environment such as the VDS improves its ability to communicate meanings associated with specific place or architecture. Beside the visual representation, Internet-based VDSs contain other channels such as audio, text-based chat, video telepresence, and interactivity which enable VDS participants to provide local interpretations of images and their significance for communities.

3.5.2. Acculturation through VDE

In a virtual design environment, digital media are the main tools for learning and practicing design. A major question to raise here is what are the social and cultural implications for architectural education and the profession as digital media become the main tools of design.

As new generations of design students spend more time practicing digital design and participating in digital environments for communication and education, it is unknown as yet, what their aesthetic demands will be. Previous research indicated that digital media tend to influence students' aesthetic values and their perception of the built environment and to alter the way in which they envision and describe architecture (Al-Qawasmi 2005). This research pointed out that students who use digital media in their design tend to produce generic forms that transcend local conventions and constraints. This research also pointed out that digital media has a tendency to offset the content in favor of the image, that is, glossy digital images stand-in for reality and "good" image becomes "good" architecture. Thus, it seems that using VDEs not only promote new aesthetic values, but also affect and change the qualities of the architectural product and how we perceive and describe the built environment.

Although it is necessary for developing countries as the Arab states to prepare their students for a fast moving digital culture and to teach them how to respond to various issues raised by the information society, they should be aware of the paradoxical and inevitable cultural outcomes of their deployment in architectural education and practice. More research is needed to examine how digital media influence students' aesthetic values, design attitudes, and perception of the built environment.

4. CONCLUSION

After more than a decade conducting networked virtual design studios, it is clear that such learning environments are not a future possibility but a present day reality whose growth potential is virtually unlimited. In light of previous experiences in conducting VDSs, there is a need to develop and implement appropriate virtual design education across the Arab region. Information technology tools and virtual learning environments bring opportunities and challenges for developing countries, and thus should be carefully examined. This thesis argued that implementing virtual design education in the Arab world may have numerous advantages such as openness to regional (sub)cultures and their architectural traditions; promoting national identities and regional identifications and associations; and promoting localism and regionalism as a reaction to uniform architectural styles and globalization of cultural values. More research is needed to examine the new virtual learning environments and the possible cultural implications of their implementations in developing countries.

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REFERENCES

AL-QAWASMI, J. 2005, "Digital Media in Architectural Design Education: Reflections on the E-Studio Pedagogy," *Art, Design and Communication in Higher Education,* 4(3), pp. 205-222.

AL-QAWASMI, J. 1999, *A study of Computer-Mediated, Collaborative Architectural Design.* Unpublished Ph.D. doctoral dissertation, Texas A&M University, College Station, Texas.

BHABHA, H. K. 1990, "The Third Space: Interview with Homi Bhabha," In: J. Rutherford (ed.), *Identity, Community ,Culture, Difference,* pp. 207-221, Lawrence and Wishart, London.

BHABHA, H. K. 1994, "Of Mimicry and Man: The Ambivalence of Colonial Discourse," In: *The Location of Culture,* pp. 85-92, Routledge, London.

CASTELLS, M. 1997, *The Power of Identity: The Information Age Economy,* Society and Culture, Blackwell, Oxford.

CHENG, N., KVAN, T., WOJTOWICZ, J., VAN BAKERGEM, D., CASAUS, T., DAVIDSON, J., FARGAS, J., HUBBELL, K., MITCHELL, W., NAGAKURA, T. AND PAPAZIAN, P. 1994, "Place, Time and the Virtual Design Studio," In: A. C. Harfmann and M. Fraser (eds.), *Proceedings of the 1994 Conference of the Association for Computer-Aided Design in Architecture (ACADIA 94)*, pp. 115-131.

DAVE, B., & DANAHY, J. 1998, "Virtual Study Abroad and Exchange Studio," In: T. Seebohm and S. V. Wyk (eds.), *Proceedings of the 1998 conference of the Association for Computer-Aided Design in Architecture (ACADIA 98,* Pp. 100-115, Quebec.

DONATH, D., KRUIJFF, E., REGENBRECHT, H., HIRSCHBERG, U., JOHNSON, B., KOLAREVIC, B. & WOJTOWICZ, J. 1999, "Virtual Design Studio 1998 - A Place2Wait," In A. Brown, M. Knight & P. Berridge (eds.), *Architectural Computing from Turing to 2000, eCAADe Conference Proceedings,* pp. 453-458, Liverpool, UK.

FOUCAULT, M. 1972, *Archaeology of Knowledge,* Tavistock Publications, London.

FOUCAULT, M. 1988, *Madness and Civilization: A history of insanity in the Age of Reason*, Vantage Books, New York.

FRAMPTON, K. 1996, "Prospects for a Critical Regionalism," In: K. Nesbitt (ed.) *Theorizing a New Agenda for Architecture: An Anthology of Architectural Theory 1965-1995,* pp. 470-482, Princeton Architectural Press, New York.

HALL, S. 1990, "Cultural Identity and Diaspora," In: J. Rutherford (ed.), *Identity, Community, Culture, difference,* pp. 222-237, Lawrence and Wishart, London.

KOLAREVIC, B., SCHMITT, G., HIRSCHBERG, U., KURMANN, D., & JOHNSON, B. 1998, "An Experiment in Design Collaboration," In: *T. Seebohm and S. V. Wyk (eds.), Proceedings of the 1998 Conference of the Association for Computer-Aided Design in Architecture (ACADIA 98).* Pp. 90-99, Quebec.

LANG, J. 1987, *Creating Architectural Theory: the Role of the Behavioral Sciences and Environmental Design,* Van Nostrand Reinhold, NewYork.

PIOTROWSKI, J. 1998, "Cultural Identity in the Era of Digital Media," In: C. Barton (eds.), *Proceedings of the 86th Associated Collegiate Schools of Architecture's (ACSA) Annual Meeting,* 258-262, Cleveland.

SCHNABEL M. A., KVAN T., KRUIFF E., & DONATH D. 2001, "The First Virtual Environment Design Studio," In: H. Penttila (ed.), *Architectural Information Management, Proceedings of the 19th Conference on Education in Computer Aided Architectural Design in Europe,* pp. 394-399, Helsinki.

STROJAN T.Z.; MULLINS M. 2002, "The Identity of Place in Virtual Design Studios," *Journal of Architectural Education,* 56 (1), pp. 15-2. MIT Press.

TAN, M. & TEH, R (eds.), 1995, *The Global Design Studio: Proceedings of the 6th Iinternational Conference on CAAD Futures in architecture.* National University of Singapore, Singapore.

VASQUEZ DE VELASCO, G. 1998, "Adding an International Dimension to our Teaching: An Application of Computer Mediated Communication Technology," In: *proceedings of the 86th ACSA Annual Meeting,* pp. 241-245, ACSA Press, Cleveland..

VASQUEZ DE VELASCO, G. AND TRIG, J. J. 1997, "Compressed Video Conferencing Technology in the Context of International Virtual Design Studio," In: J. Edwards & T. Gelsanliter (eds.), *proceedings of the 85th ACSA annual meeting,* pp. 500-505, ACSA Press, Cleveland, Ohio.

WOJTOWICZ, J. (ed), 1995, *Virtual Design Studio.* Hong Kong University Press, Hong Kong.

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DIGITAL MEDIA INSTRUCTION IN ARCHITECTURE EDUCATION

Antonieta Angulo

Abstract

The aim of this paper is to provide a structured collection of case studies organized around the core discussion of how to address the subject of digital media in schools of design in general and architecture in particular. By means of these case studies it will be possible to understand the trajectory that we have followed in the Department of Architecture at Texas A&M University, having as main goal the incorporation of digital media instruction in design curricula and to assess whether our instructional methods and strategies are in tune with our present understanding of the role of digital media in design. The case studies have been organized following three main contextual themes, namely: shaping our understanding of the role of digital media in design, incorporating digital media in the design studio, and adapting to the availability of new technology. The paper includes the identification of critical issues, among them: polarization between traditional and digital media, solutions for continuous learning and update, and pervasive accessibility of digital means. The paper states conclusions and identifies the opportunities and challenges that we foresee in the near future based on the implementation of multidisciplinary integration and the development of multimodal and media- rich design environments.

Keywords: Digital Media Instruction, Design Studios, Design Education, Multimodal and Media-Rich Integration, BIM.

1. DOING, LEARNING AND RE-DOING: THE UNCHARTED AND DYNAMIC NATURE OF THE DOMAIN

Texas A&M University is home to the largest College of Architecture of its kind in the United States. At the same time, this is a school of Architecture that has taken an early interest in the application of computer technology in the teaching and practice of design. As several institutions that took an early interest on architectural computing and defined the historical mainstreams (Maver, Schlif 1983; Mitchell, 1984), we have extensively experimented on similar and alternative strategies for the introduction of digital media into our curriculum. We have created a curriculum for digital design media that has departed from simply mimicking the teaching of analogue media and has moved towards identifying the different roles of computing in the production of documentation, as a medium for design, and for collaboration among design partners. Nevertheless, we do not claim to have full understanding of the potential of the domain and continue to experiment on how to address our rapidly changing instructional needs. In such an experimental instructional environment we find that constant analysis, evaluation, and feedback are very useful and the global dissemination of relevant case studies is of critical importance.

2. CASE STUDIES

These case studies have been organized following three main contextual themes, namely: shaping our understanding of the role of digital media in design, incorporating digital media in the design studio, and adapting to the availability of new technology.

2.1. Learning as we go: shaping our understanding of the role of digital media in design

When we design, we produce cognitive inferences that build complex problem-solving and decision-making structures. In architecture these complex structures take the form of mental images of buildings. We do this with great skill and speed, but as the complexity of such structures starts to exceed our capacity to see them clearly with the eyes of our

minds, we feel the need to download these mental images into external media that will make them factual and the subject of communication with our own intellect and the intellect of others (Schon, 1983; Goel 1995). Traditional and digital design media support can facilitate this process in different ways. How we use digital media in design depends largely on our level of exposure to technology and its availability in the environment where we first learn to design. The following case study illustrates how we have addressed the training of digital media and promoted its integration into the design process.

Computer literacy (The ENDS270 / ENDS170 case study)

Fifteen years ago, we concentrated on teaching how to create software routines that would aid and enable the design of architecture. In that framework it was very important to convey to the students the notion of the computational processes that eventually lead to the solution of well-defined problems in design. Later, with the gradual availability of general-purpose off-the-shelf programs the attention was switched over to the more pragmatic aspects of learning how to make design representations with computers. At first our objectives were ill-stated as the "teaching of software programming" or the "teaching of software" instead of the ideal objective of "teaching to design using software". Following a period of time in which CAD was an elective subject, the one required CAD course of our curriculum was set in the sophomore year of the undergraduate program for the teaching of "Computer Techniques for Building Design and Analysis" (ENDS270). At that time we taught the history and theory of computational design, and also gave software demonstrations that were followed by small creative exercises with whatever software was available (in our case first in a UNIX platform and later in a PC platform). Less than a decade ago this course evolved and now is being taught earlier in the freshman year as "Computer Techniques for Design Visualization" (ENDS170). In this class, the students are introduced to computer methods for vector editing, image editing, modeling, rendering, animation, and web publishing. With so many techniques to teach, other issues regarding history and underlying principles of computing are being addressed more superficially. In addition to teaching how to use each technique at a time, we focus mainly on showing how tools can work together. Usually in the final project, the students make use of a series of applications emphasizing the portability of data, demonstrating interoperability between applications, and showing a product that is the result of several iterations among different computer techniques.

In the context of this first case study, several curricular issues demand our constant attention, among them:

- The issue of "when" the students should learn to use digital media. This issue tends be get polarized on the question of doing so before or after mastering the use of traditional media. Our experience is that the order in which the students learn to use media is irrelevant as long as it is early in their exposure and development of design methods. In our case, half of our students take traditional media in their first semester and the other half is simultaneously exposed to the use of digital media. In operative terms this arrangement also allows us to reduce the number of students we need to serve simultaneously with formal computer classroom infrastructure.
- The issue of "what" should we teach in the curricula of digital media. This issue gets cen-

Fig 1. The Student Computer Center (SCC) where we teach the ENDS170 classes

tered in the discussion about limitations in the amount of content that can be delivered in a single required course. The subject of digital media for design is broad and deep in content. There is so much to teach and so little time. Unfortunately, curricular constraints have not allowed us, and most schools of architecture, to promote a larger number of required courses on digital media. The fundamental answer to the question of "what" to teach tends to be found in the intersection of what we "can" and what we "must" teach. Our experience is that faculty who can and does teach design studios at the same time that teach CAD courses have the ability to negotiate this question with much more effectiveness than exclusive CAD instructors or design professors.

- The issue of "how" to teach and learn the use of digital media. This issue is in particular problematic given the fact that freshman classes exhibit great diversity in levels of expertise. A survey implemented at the freshman level showed that most of the students are coming better prepared with prior practical experience in computing. These skills are mainly related to text processing, web searches, and e-mail. Few students have no prior computer experience but there is also a small group of very well-prepared students who already know most of the basic techniques related to digital design media. Our experience has guided us to provide instruction at an average level of expertise but this necessarily means that we need also to provide additional out-of-class assistance to the most needy students and additional instructional challenges to the more advanced students. We don't think this is an effective way of addressing this issue.

2.2. Digital media in the design studio: incorporating digital media in the design studio

The incorporation of digital media into the design studios is of relevance in this study because it allows us to understand what needs to be taught in design media courses (pre-requisites) and how two learning curves (design and media) impact the cognitive load of students (Vasquez de Velasco & Clayton, 1998). Three case studies illustrate the gradual incorporation of digital media in design studios: the electronic design studio, the virtual design studio, and the fabrication design studio.

Electronic Design Studios (The EDS / DDS case study)

When the design studios migrated for the first time into a centralized computer lab, we coined the term "Electronic Design Studio" (EDS). This brief experimental implementation took place no more than 13 years ago with 34 Silicon Graphics Indigo (SGI) machines running Alias Sonata, a 3-D modeling program with parametrically defined components. The EDS served mainly the graduate and senior undergraduate students who were trained in the use of the program at the same time that they learned how to solve design tasks. The elevated costs on hardware maintenance and the lack of acceptance of the software in the profession led to the rapid transformation of the EDS into centralized CAD ateliers where PC's and commercially available software platforms (i.e. Autodesk products) were available. These "Digital Design Studios" (DDS) that run in parallel to traditional media based studios, aimed to integrate design with computing. The DDS imposed a radical change in the design studio culture. It had a positive effect due to the quick visualization of projects that allowed for the fast assessment and speedy evolution of even the largest projects in a short period of time. In some cases, the students made use of innovative graphic techniques for generating unusual and imaginative imagery mainly during the conceptual stages of the design. However, the EDS first and the DDS later also negatively affected some faculty who manifested difficulties in adapting traditional methods for teaching design through the production of representations with the "new media". Sometimes the students' computer skills far surpassed those of their mentors and that also brought some uneasiness among faculty. Nowadays we are still getting over the initial years of EDS and DDS development manifested through digital media-exuberance. In this period the pervasive use and misuse of image editing techniques (too many image layers!) and digital rendering in absolute replacement of traditional technical drawings and hand-made analytical perspectives

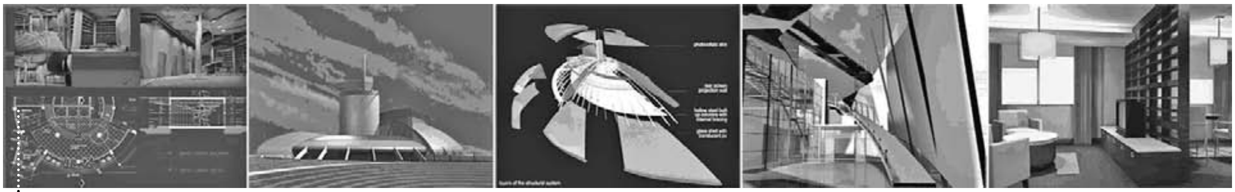

Fig 2. Digital media projects

brought some bitter criticism. For a brief period, our EDS was exclusively "paperless". Instructors and students implemented experimental methods for design exploration and communication that relied solely on the digital media. While design products of this period are not necessarily the measure of the validity of this approach, we have harnessed specific knowledge on the limitations and opportunities of digital design processes. We no longer struggle with validating the contribution of digital media to design education and the profession against the once prevailing notion that using traditional media is the only way to be creative. The digital media has become so widely available and pervasive in the curricula that most of the studios, graduate and undergraduate, make use of digital and traditional media in many different creative ways: what we promote now is the opportunistic integration of traditional and digital methods for process, communication, and presentation.

Virtual Design Studios (The Tex-Mex and Las Americas case studies)

Following the trend of collaborative virtual design studios of the early 1990's (Wojtowicz, Davidson, and Mitchell, 1992) we implemented our first version of virtual design studios as a spin-off development of digital design studios and videoconferencing facilities. This studio, known as the "Tex-Mex Virtual Design Studio", run between 1996 and 1998, and articulated Mexican and American students (Vasquez de Velasco, Jimenez 1997). The collaboration between students in Texas A&M University and La Salle University in Mexico City was a semester-long. The WWW became the virtual studio medium (web sites, e-mail, ftp, telnet, whiteboard). The video-conferencing was the technological means that allowed for face-to-face communication between participants and the accomplishment of very high levels of project development.

Given the success of our first virtual design studios and again under the initiative of Texas A&M, a second version of virtual design studios was implemented in 1999. The "Las Americas Virtual Design Studio" (Vasquez de Velasco, 1999) has included throughout the years the participation of an average of 14 schools of architecture from Latin America. Despite the sheer size of the implementation, the studio dynamic remains the same with active participation and collaboration between international and virtual students and reviewers. For some time, the communication based on video-conferencing was limited (possible only with Mexican and Chilean partners), and relied more on

Fig 3. The Tex-Mex Virtual Design Studio Environment

Fig 4. The Las Americas Virtual Design Studio Environment

web site and e-mail communications. Lately, video web cast through Internet 2 is a common practice among partners. The virtual sessions include presentations followed by reviews and debates.

The Fabrication Design Studio (The laser-cutter/ rapid prototyping/CNC milling machine case study)

After the acceptance of digital media in the design environment, the tendency has reverted into a more open and opportunistic use of all media, including traditional media. We have embraced the concept that the use of multiple media reinforces the project understanding (Cheng, 1995; Bermudez & King, 1998) and that translating the design project from one medium to another can lead to new directions and it would encourage refinement. The conversion among media provides opportunity for reflection and encourages the implementation of multiple cycles of creation, re-assessment, and re-definition. The re-articulation of the project into new medium forces to consider what is essential and what is vestigial. Among our design studios, the integration of 2-D analogue and digital media by means of flat bed scanners and printers is very common and already yields satisfactory results in terms of implementation and educational objectives. Lately, we are also promoting 3-D media integration by means of fabrication / rapid prototyping machines (RP) and 3-D laser scanners (Angulo, 2005). As a result the studio has started to migrate into the fabrication workshop in a similar way as the studios migrated into the computer laboratories some years ago. From our past experience, we expect that initially the available RP, laser-cutter, and CNC milling machines will be only used as a means to facilitate the production of scaled physical models and mock-ups, as it was in the case of computers when they were only utilized for the production of drawings. In this context, the laser cutter and CNN machines have proved to be well-accepted and regularly used by the students. It is not the same case for our RP machine (Fuse Deposition Moldering technology) where the added value of

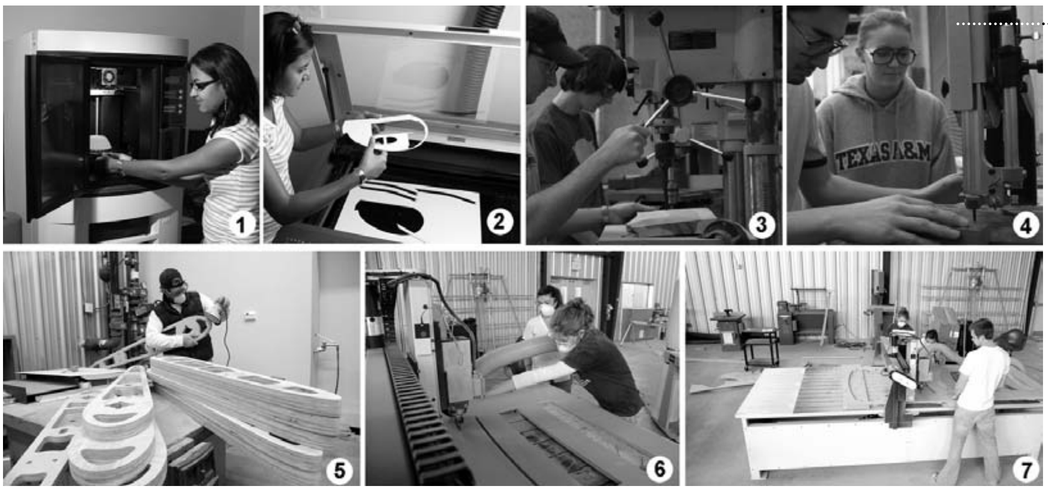

Fig 5. The College of Architecture Fabrication Facilities: 1) FDM rapid prototyping machine, 2) Laser cutter, 3)4) Woodshop, 5)6)7) CNC milling machine

the resulting prototypes comes with a very high cost in time and money that discourages its utilization. Initial experiments using the 3-D laser scanner at the Archeological Preservation Research Laboratory at Texas A&M University have yielded positive results, especially during conceptual design stages, and validate the inclusion of shape grabbing and digitization of models in design. Following a parallel development to the one foreseen for computers in design studios, we will continue exploring the use of fabrication/scanning techniques and related methodologies as media for design and not simply as tools for the production of final models.

2.3. Media instrumentation: adapting to the availability of new technology

Adapting to the availability of the digital technology is a continuous challenge. The efficiency of any implementation is measured by not only the satisfaction of quantitative needs but also by the appropriateness it holds with our instructional objectives. Three case studies describe the evolution and tendencies through which we have adapted:

- Centralized computer laboratories committed to provide maximum IT access to the students. In addition to access to a standardized computer environment mainly directed to the teaching of computer techniques, students need to constantly practice and apply their newly acquired knowledge without restrictions. In order to address this need, not only the computer classes were delivered in the computer labs but also the students used them to practice and develop their assignments. The large demand of the required classes (sometimes 7 sections of 24 students each) put to the test the infrastructure of the College, and in many instances, the demand had to be addressed through University-level laboratories (Student Computer Center). When the DDS's became generalized, the enrolled students became also users of these centralized laboratories adding to the demands of the regular computer classes. The system administration of these labs faced the enormous task of implementing, maintaining, and upgrading hardware and software on a constant basis. Other peripheral services as 2-D printing and scanning, and reproduction were also stressed. A related problematic issue was the migration of students out of the studios and the apparent loss of studio culture and peer dynamic.
- Computer resources in studio areas. Seven years ago in addition to the computer laboratories, a system of network connections and a power grid was installed in the graduate design studios together with the availability of desktop computers for all the graduate student popula-

Fig 6. Evolution and adaptation of the studio environments: 1) Traditional design studio, 2) Paperless Electronic Design Studio, 3) Digital Design Studio, 4) Cold Station, 5) Computer laboratory for lectures, 6) Traditional and digital integration, wireless ubiquitous computing.

tion. Some undergraduate digital design studios also selectively borrowed pallets of notebooks administered by the digital media administration of the College. A small number of peripheral components (laser printers) were distributed in the graduate studio area but for the most, components remained centralized in one location at the "media center" (for digitizing, printing, copying, and other media exchange operations). The computers that were distributed among graduate studios were 3-year old, coming out of the centralized computer lab rotations and were largely outdated. Nevertheless, their availability did help reduce the level of migration out of the studios that was previously very evident.

- Recently, the availability of wireless networks has initiated the phenomenon of ubiquitous computing provided by the students themselves. Personal computing is required from all students of the freshman and sophomore levels; others have increasingly followed the trend. Computer and software vendors offer academic special prices and compete for the attention of our students at the same time that digital instrumentation is included in university financial aid packages. With these incentives, there is no reason to foresee any drawback to this new strategy. Our academic institution is therefore only dedicated to offer better bandwidth connections, provide the services of state-of-the-art "media centers(s)", and invest in high-end specialized peripherals (i.e. plasma screens with interactive layer, and fabrication/digitizing machines).

3. WHAT WE HAVE LEARNED

The most fundamental lesson we have learned from the analyses of the case studies that describe our experience of the last 10 years is that the individual experiences lack the holistic framework that can provide us with sustainable answers to all our strategic and tactical questions. It is only through the integration of digital design media courses, design studios, and computer infrastructure relevant to our teaching mission that we can achieve our objectives.

The discussion on whether the students must learn first traditional or digital media is irrelevant. Furthermore, the design principles, symbols, and conventions for communication are common to any project and are media independent. On this basis, students should find similarities across traditional and digital media, and at the same time, learn to express the same architectural values in any media. The real challenge is to facilitate opportunities in the translation among media.

It is not possible to address within a single syllabus the learning needs of an extremely diversified group of learners. Currently required courses concentrate on design media application strategies within design methodologies (in a studio environment). As students come to college with unprecedented software fluency, instructors are looking for ways technology can help foster creativity, communication skills, and critical thinking. We are also in the process of developing state-of-the-art e-Learning tutorials (Angulo, 2006) as a means for skill leveling and elective courses for high-end digital media expertise.

It is not realistic to increase the number of required curricular hours dedicated to computer techniques, or try to fit all computer techniques in one single course. The educational strategy that we have been implementing throughout many years is to teach "to learn how to learn", so the students don't feel unprepared when changes or new technologies arise. In this context, we are also making use of metacognitive strategies that reinforce reflection and re-assurance of learning (Angulo, 2006). If students become aware of their own learning needs they can gear their own training by following selected "learning how to learn" strategies.

Access to computer resources must be pervasive. We need to maintain computer laboratories for the delivery of prescriptive computer operational skills. The instructors demand an instrumental framework in which all computers are configured in identical matter. On the other hand, the students should not rely on those laboratories for the development of assignments and design studio projects. Personal computing should populate the design studio environment making possible the reestablishment of a design studio culture and the benefits of a rich peer-review environment.

4. WHERE TO GO NEXT

Aware of the critical importance of coherence in the articulation of "when", "what" and "how" we teach digital design media and design, we have decided to emphasize multidisciplinary integration and the development of multimodal and media- rich design environments.

In terms of software use, we will emphasize multidisciplinary integration through the use of BIM programs. Allowing everyone involved in a project to access the BIM data-base promotes multidisciplinary integration. The Building Integration Modeling standard (BIM) instrumented in several off-the-shelf software platforms gives multi-user access to a single building model with drawings treated as graphical reports (Autodesk, 2002) This integrated building model enables the design and construction teams, among others, to extract almost instantly, much richer information than they could get from 2-D drawings. Since 2005, we have adopted the BIM software Autodesk REVIT for our freshman digital media course; we expect that the students will use BIM programs to produce projects more thoroughly developed and refined than with 3-D tools alone. It will be required that students learn more about how building components and systems can be integrated into the functional/formal design. Integrated building modeling tools are not necessarily more expensive or more complicated to use than more widely deployed CAD systems. We have strategically decided that by using BIM tools the students can focus more on learning to design by integrating building systems instead of just focusing on unrelated techniques for drafting and 3-D modeling. Quoting Paul Seletsky on the impact of BIM and education: in a BIM-enabled process, individual students … are also encouraged, and (most importantly) enabled, to act upon their ideas by digitally analyzing, critiquing, and then simulating conditions portraying those ideas. This in turn can lead to design conditions "informed" by data, finalized into an assembly "informed" by conditions-fed analytically as well as intuitively (Seletsky, 2006)

In terms of hardware, our design environments will continue to be based on the design studio, which safeguards the non-negotiable function of promoting peer review among students, but can additionally facilitate the integration of diversified media without instrumental limitations. In this vision, the traditional design studio will also be a hybrid of computer laboratory, videoconferencing site, and fabrication workshop. We have been successful in the introduction of this level of instrumentation but we have done so in a constellation of separate environments that fails to provide an opportunistic framework for their integration in the design process. We look forward to the implementation of this kind of multimodal and media-rich environment, first at a prototypical level and following its assessment, we hope to propagate this kind of environment until meeting the large demand of our Department of Architecture.

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REFERENCES

ANGULO, A (2005) "*Beginners' IT Instructional Support Environment*", in Proceedings of the 2005 International ACSA Conference, México City, 237-243.

ANGULO, A (2006) "*Communication in the Implementation of a Metacognitive Strategy for Learning to Design*", in Proceedings of the 2006 eCAADe conference, Volos, Greece. ISBN: 0-9541183-5-9

ANGULO, A. (2006) "*Optimization in the Balance between the Production Effort of E-learning Tutorials and their related Learning Outcome*", in Proceedings of the 2006 SIGRADI conference, Santiago, Chile. ISBN: 956-19-0539-6

AUTODESK (2002) "*AUTODESK BIM White Paper*" (2002) Available:
http://www.laiserin.com/features/bim/autodesk_bim.pdf

BERMUDEZ, J. & KING, K. (1998) "*Media Interaction and Design Process: Establishing a Knowledge Base*", in Proceedings of the ACADIA Conference, Québec City (Canada) October 22-25, 1998, pp. 6-25

CHENG, N. (1995) "*By All Means: Multiple Media in Design Education, Multimedia and Architectural Disciplines*", in Proceedings of the 13th European ECAADE Conference, Palermo (Italy) 16-18 November 1995, pp. 117-128

GOEL, V. (1995) *Sketches of Thought.* Cambridge, MA: MIT Press.

MAVER, T. and SCHIJF, R. (1983) "*International Implementation of a CAAD Project in Schools of Architecture*", BoCAAD #47, February 1983, pp-3 -8.

MITCHELL, W. (1984), "*CAD Technology, Its Effects on Practice and the Response of Education - an Overview*", in Proceedings of the Third eCAADe Conference, Helsinki, Finland.

SCHON, D. (1983). *The reflective Practitioner.* New York, Basis Books.

SELETSKY, P. (2006) "*Questioning the Role of BIM in Architectural Education: A Counter-Viewpoint*" in AECbytes Viewpoint #27 (August 31, 2006). Available: http://www.aecbytes.com/viewpoint/2006/issue_27.html

VASQUEZ DE VELASCO, G. & JIMENEZ, J. (1997) "*The Tex-Mex Virtual Design Studio*", in Proceedings of the 6th International EuropIA Conference, pp 167-180

VASQUEZ DE VELASCO, G. & CLAYTON, M. (1998) "*Integrating Introductory CAAD Courses and Upper Level Electronic Design Studios*", in Computers in Design Studio Teaching, EAAE/eCAADe International Workshop Proceedings, Leuven (Belgium), pp. 157-164

VASQUEZ DE VELASCO, G. (1999) "*La Red Digital de Investigación "Las Américas": Una herramienta de colaboración*" (The Digital Research Network "Las Américas": A Tool for Collaboration) in Proceedings of the 3rd International SIGraDi Conference, Montevideo (Uruguay), pp. 384-388.

WOJTOWICZ, J., DAVIDSON, J. and MITCHELL, W. (1992) "*Design as Digital Correspondence*", in ACADIA Conference Proceedings, pp. 89-101.

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AN AGENT-BASED SMART SKIN FOR BUILDING SMART HOMES

Shang-Yuan Chen

Abstract

The smart open house provides optimal adaptability using sensing, operating, information, and communications technology, in conjunction with open building in-filled components, to perceive user needs and environmental changes, and thereby meet the needs for sustainability and a healthy living environment. These needs are particularly pressing in view of the aged society that will emerge in Taiwan after 2020. Based on the smart open house hypothesis, this study proposes using agent-based smart skins in a smart open house, where an agent-based smart skin is embedded in a lifetime home (or ageless home) with an open system construction. The agent-based smart skin operating mechanism employs fuzzy logic inference and neuro-fuzzy learning to process environmental information from sensing devices and drive skin elements, achieving adaptive action, meeting residents' lifetime use needs, and offering a user experience-oriented smart care capability.

Keywords: *Lifetime Home, Open Building, Intelligent Agent, Fuzzy Logic and Neuro-Fuzzy, Smart Care.*

INTRODUCTION

Traditional static buildings are full of immobile objects that cannot respond to immediate and dynamic changes in the external environment. Although the open building is accepted as a building variation (Habraken, 2000: 59-72) with an established theoretical foundation, an open building nevertheless lacks smart mechanisms, cannot perceive changes in the environment, determine times when change is needed, or provide adaptive solutions. Responding to the contemporary need for sustainability and the demands of the coming aging society, this study proposes to establish a smart open house incorporating artificial intelligence into an open building system.

Based on the smart open house hypothesis and a review of the literature, this study attempts to establish a basic theory of smart open systems and takes agent-based smart skins as its focus. Apart from laboratory simulations, the agent-based smart skin concept has been realized in a home con-

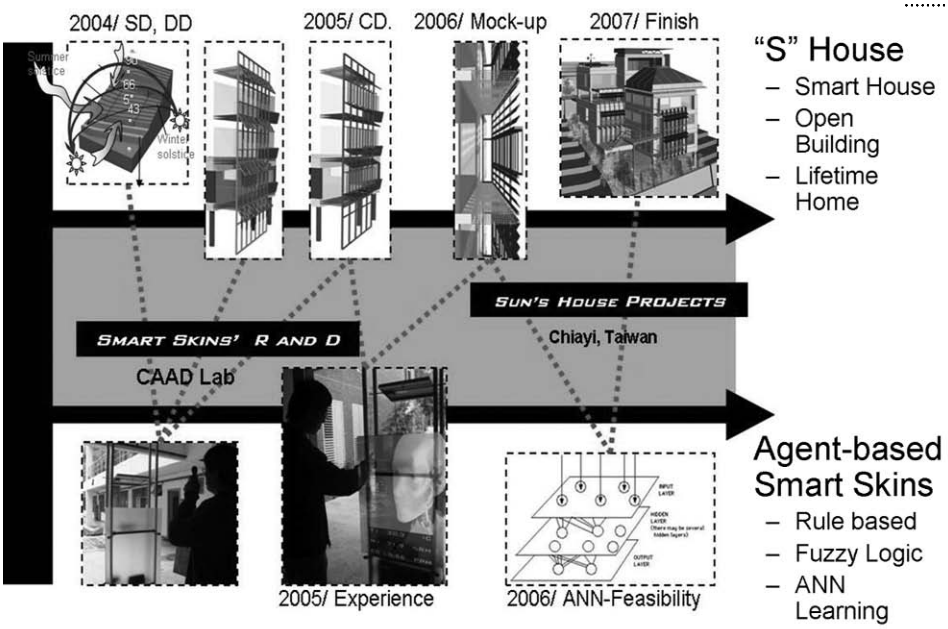


Fig 1. S House research, practical plan, and timetable

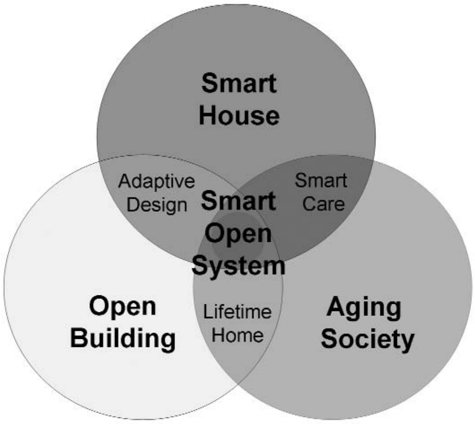


Fig 2. Building a smart open system

structed as an open system and suitable for use by the elderly - S House. A smart open system research subtopic (Figure 1) is proposed here following experimental assessment.

LITERATURE REVIEW

Technological advances resulted in an astonishing revolution in housing technology during the 20th century. The first quarter-century saw the adoption of electricity in the household, and information technology exerted a major influence during the final years. A smart home can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond (Aldrich, 2003: 17-18).

In short, sensing, computing, and communication technology can be used to create smart houses possessing open smart systems. We can expect that smart houses will inherit an open building's ability to adapt to variation. Figure 2 shows how the open building concept can be used to create smart homes meeting the needs of an aging society. The lifetime home shown schematically in this figure has the smart open system concept as its integrating core; the home features an adaptive design and possesses smart care functions.

The Netherlands' SAR (Stichting Architecten Research) proposed the concept of separate support and infill in the 1960s, which led to the integrated analysis of users' lives and existing systems. This work led to the suggestion that a modular grid can be used as a layout coordination tool to achieve reasonable and effective zone layout (Figure 3) and grid analysis (Figure 4). In the late 1970s, open construction sought to provide supports with diverse spatial arrangement. The 1980s and '90s saw the development of infill (e.g. Matura; Esprit), which was used in the commercial realization of open building theory (Habraken, 2000: 9-10). Responding to the need for sustainable construction, the time since the 1990s has seen the development of building interface technology (Lin, 2002: 10-12).

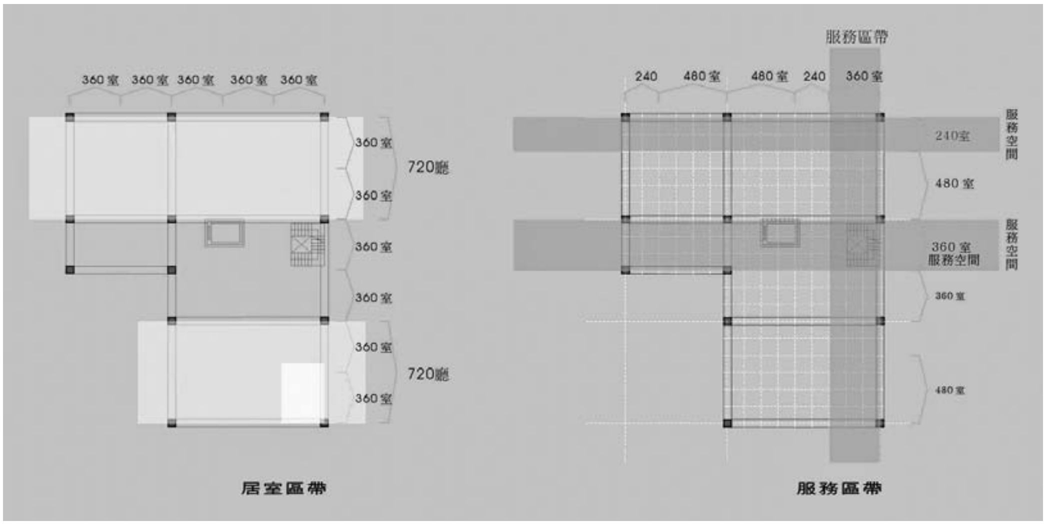


Fig 3. Zone analysis of S House

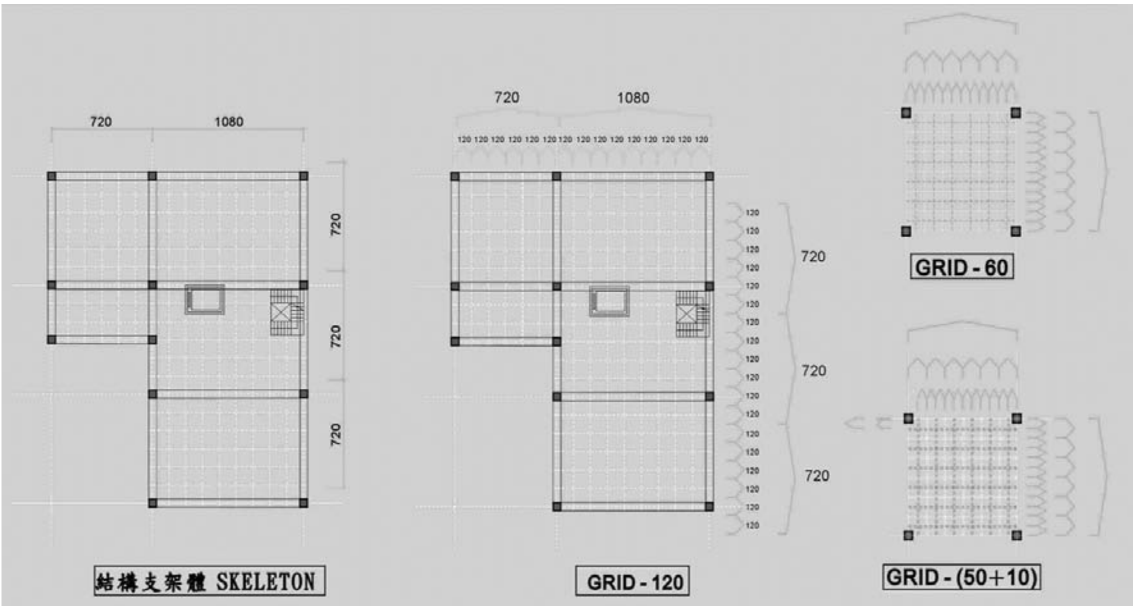


Fig 4. Grid analysis of S House

The open building concept emphasizes the building life cycle and interaction with the user's lifestyle. From a macro perspective, the building life cycle includes preliminary planning, construction, and use (including modifications, upgrades, and maintenance). Ideally, the in-filled components of an open building can be modified, upgraded, and maintained (Hsieh, 2005: 3-9) in response to different building life cycles. An open building possessing artificial intelligence can determine living conditions and actively adjust its in-fill components in order to satisfy users' immediate living needs.

Taiwan's society is experiencing demographic aging. According to the Demographic Projections for the Taiwan Area, 2004-2051 issued by the Council for Economic Planning and Development, the elderly will constitute 15.74% of Taiwan's population by 2020. Although it will be necessary to develop in-home service before that time, because people expect less care from their children in old age, and because of the growing number of nuclear families, in-home care of the elderly may prove very difficult (Chen, 2006: 87). The concept of the lifetime home is a necessary response to the aging of society. A lifetime home should possess functional flexibility and accommodate residents' abilities and needs throughout all stages of life. A lifetime home should adapt to users' living needs in different stages of life (including when healthy, disabled, and bedridden), so that users can enjoy aging in place (Hsieh, 2005: 3-1).

Nevertheless, from a short-term, micro perspective, changes in residents' behavior in everyday life far exceed changes expected during the life cycle of a building. In other words, emphasis on a building's life cycle (including changes to in-fill components, maintenance, and updating) is insufficient to respond to short-term, dynamic changes in residents' everyday use. For instance, when an elderly person in a wheelchair falls asleep in a space defined as a living room, the function of that living room should change to that of a resting room. The angle of the sunshading device should then be adjusted to reduce indoor illumination and the transparency of the screen should be reduced to increase privacy. Later, when the person awakes and grandchildren enter, the function of the resting room is restored to that of a living room. From a micro perspective, residents' need for adaptive functions in everyday life is far greater than their need for macro, long-term variation.

THEORY AND METHOD: BUILDING AN AGENT-BASED SMART OPEN SYSTEM

Several smart house cases and smart open systems in particular were examined . In such well-known cases as the MIT's House_n, Aware House,

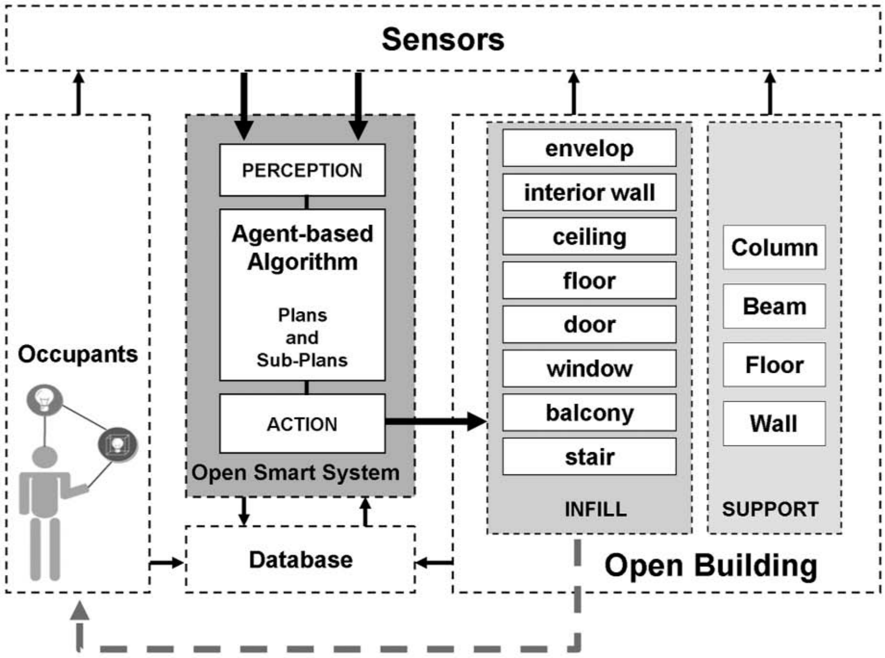


Fig 5. Integration of user needs, smart open system, and open building system

Adaptive House, TRON House, and Toyota Intelligent House PAPI, researchers have both explored new digital technology and also emphasized that the integrated application of sensing hardware and software must meet users' needs (Chen, 2005). In addition, in contrast with past focus on centralized intelligent control systems in home automation, this study proposes the use of intelligent agents to establish smart open systems. This refers to use of individual intelligent agents or intelligent agent societies in a distributed intelligent environment to perform communication and coordination via a network and user interface. The intelligent agents drive the building's in-fill components and perform adaptive smart actions meeting users' dynamic living needs.

Intelligent agent technology is currently one of the most important topics in the field of artificial intelligence. Intelligent agents involve the integrated use of sensors, computers, and information networks. Intelligent agent societies and multi-agent systems apply ubiquitous computing, interaction and communication, intelligence, authorized agents, and humanistic design in order to create intelligent network-based distributed computing environments (Wooldridge, 2002: 23-25). The internal elements of independent intelligent agents are assembled into modules in accordance with the principle of cohesion so as to maintain the agent's autonomy. Furthermore, agents must reduce external coupling as much as possible in order to maintain the openness of the agent community (Padgham, 2004: 1-20, 55). The intelligent agent concept facilitates the integration of sensors and various in-fill components such as door agents and window agents. Figure 5 shows an agent-based smart open system. Sensors embedded throughout the house perceive variations in the environment, and intelligent agents use inductive learning with a knowledge base or database to perform optimized, intelligent actions. This study uses agent-based smart skins to further investigate the applications of smart open systems.

It has proven difficult for designers to select appropriate technologies and determine algorithms and control conditions when creating intelligent environments. For example, the TU Vienna Test-bed (Mahdavi, 2005: 45-66) employs a rule-based control system in which meta-controllers must be added as the number of devices increases. This system consists of a distributed, hierarchical control node framework. The fact that it is not easy to distinguish modules in the system increases the difficulty of control and rule description. In another example, Adaptive Home (Mozer, 2005: 273-294) employs Adaptive Control of Home Environment (ACHE) to strike a balance between maximum user comfort and minimum energy consumption.

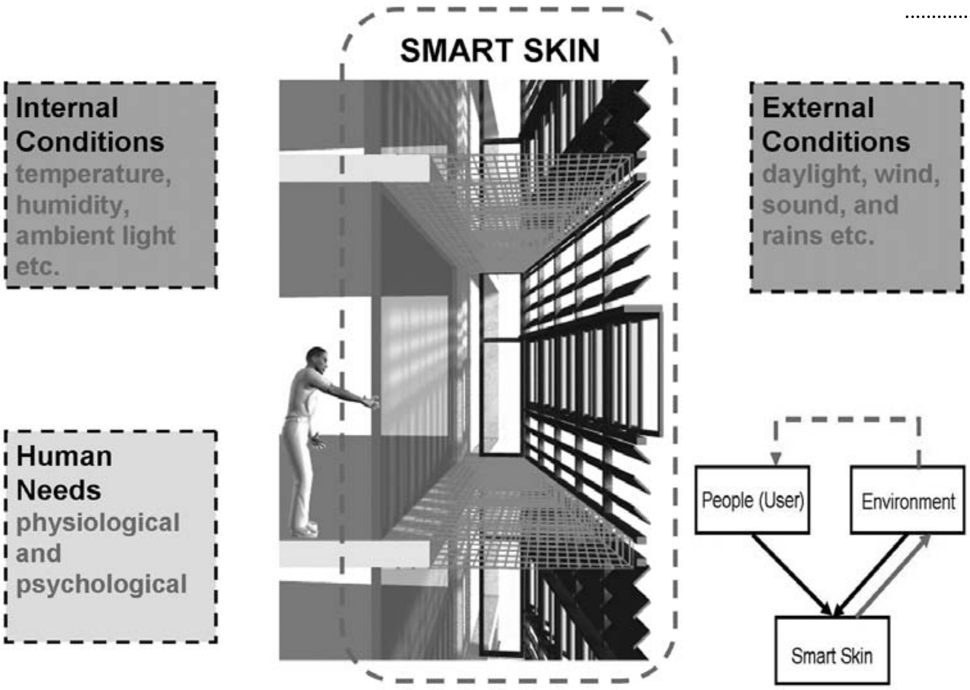


Fig 6. Basic functions of smart skins

However, because the central control system's X-10 controller is often slow to respond or out of order, or because of improper operation, the neural system tends to make learning errors and converge on a state of low energy consumption and low comfort.

After examining the advantages and disadvantages of these two cases, this study proposes the use of a fuzzy logic and neuro-fuzzy system as a computing mechanism. This type of system can use prior knowledge and fuzzy logic to make inferences, while also employing neuro-fuzzy learning to reduce the error between inferences and reality (Negnevitsky, 2005: 87-127, 268-284). Solutions obtained by conventional binary rule-based control elements via inference must consist of truth values of 0 or 1. There must therefore be a meta-controller to help perform further judgment when a conflict between rules occurs. Fuzzy logic is nevertheless able to obtain truth values between 0 and 1 from vague, ambiguous, and imprecise information. Via the definitions of linguistic variables, membership functions, and fuzzy reasoning, a fuzzy logic reasoning system can use weighting to resolve conflicts, and does not need additional control nodes. A fuzzy logic reasoning element consequently can be seen as an independent smart module. Moreover, in comparison with other neural technologies, neuro-fuzzy offers the following advantages: (1) Because it starts with built-in fuzzy logic system, the freedom of neuro-fuzzy learning can be controlled, and learning errors can be avoided. (2) Because prior knowledge can be inherited from the fuzzy logic system, the results of learning can be read or subjected to inference. (Pal, 2004: 231-252)

In summary, this study will develop an agent-based smart open system, and suggests the use of a fuzzy logic and neuro-fuzzy system as the intelligent agents' computing mechanism. This system can employ inference and learning to implement adaptive actions and functions. The agent-based control system can be divided into two layers; the first layer consists of the computing mechanism and planning of independent agents, and the second layer consists of a description of the agent community interaction mode.

Definition of agent-based smart skins

Agent-based smart skins constitute interfaces for communication between occupants and the environment. An agent-based smart skin should be able to simultaneously sense occupants' physiological or psychological needs and fluctuations in the environment, which includes both the external environment (sunlight, wind, noise, rain, etc.) and the internal environment (temperature, humidity, artificial lighting, etc.). The agent-based smart skin can

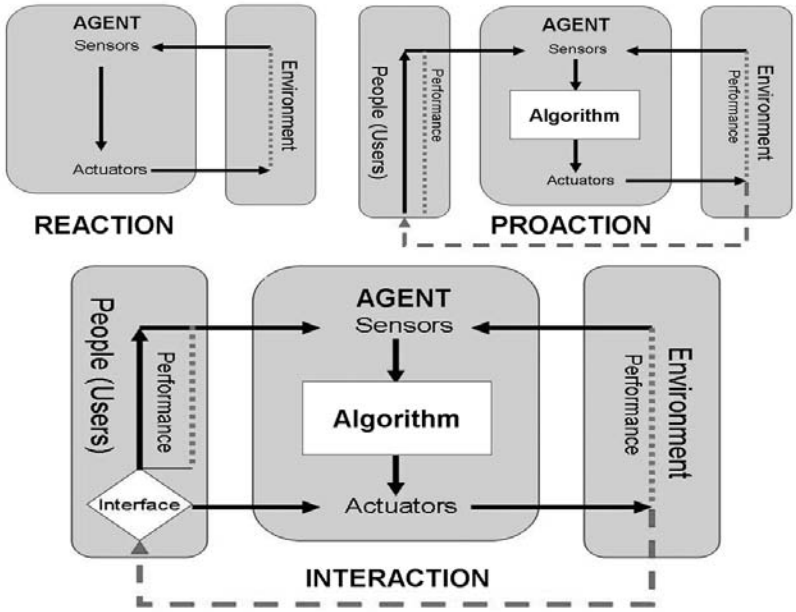


Fig 7.
Adaptive behavior by intelligent agents

respond by activating or turning off the building shell's in-fill components, and thereby controlling the environment. Apart from improving comfort and health conditions, the smart skin must also be able to meet the requirements of sustainable development (Figure 6). Furthermore, in accordance with the design goals, a smart skin should be able to assign at least one agent or societies of agents to perform tasks or accomplish overall goals.

Smart modules

Intelligent agents consist of sensors, computers, and actuators, including software and hardware (Russell, 2003: 32-58). Agents process information received from sensors or other agents via an event-driven model, and then drive the building's in-fill components in accordance with plans or sub-plans. An agent can perform reactive, proactive, and interactive adaptive behaviors. Reaction refers to immediate action taken by an agent without computing after receiving information. Pro-action refers to action taken following computing after receiving information. Interaction refers to communication between an agent and another agent or an occupant via a human-computer interface (Figure 7).

Intelligent agent societies

Agent societies or agents and users can generate cooperative or coordinated interactive behaviors via common communication protocols, shared databases, messages, and human-computer interfaces (Wooldridge, 2002: 23-25). The levels and subordination relationships of agents within a community are not fixed, and can be changed or reassembled to suit the task or overall goal (Minsky, 1988: 34-35) (Figure 8). Testing and mode analysis is presented in section *"Environmental settings and implementation"*

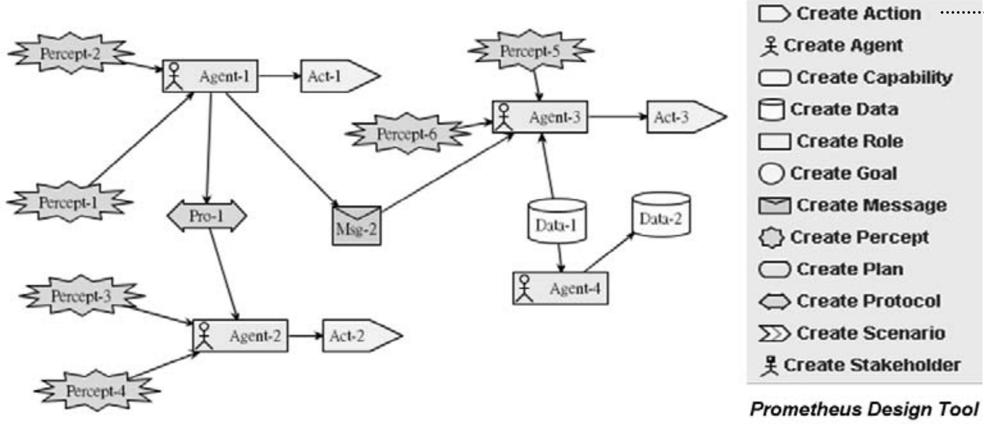


Fig 8.
Interactions in a community of agents

	User Types	Interface prompt	Adaptive actions
Level 1 、Norm (Interface alert)	Ordinary people	Yes	Passive (User Driven)
Level 2 、Aging (interface prompt and user selection)	Healthy seniors	Yes	Interactive
Level 3 、Disability (Pro-active assistance)	Disabled persons or impaired seniors	No.	Reactive Pro-active

Table 1.
Smart care levels

Smart care levels

The user experience-oriented three smart care levels of (1) Ordinary people (interface alert), (2) Healthy seniors (interface prompt and user selection), and (3) Disabled persons (proactive assistance) can be defined depending on whether there is a human-computer interface and on the adaptive behavior mode of the actuator. As shown in Table 1, the interface prompted interaction mode is suitable for ordinary people and healthy seniors. On the other hand, the disabled can employ the proactive assistance mode, where agents can perform inference and learning without the occupant having use the interface. (Note: Passive refers to when the user purposely adjusts the building's elements and the actuator operation is not controlled by agents. An example is when the user opens or closes the window without the use of agents.)

Prior research (Chen, 2005) has verified that agent-based smart skins are able to implement simple context-aware functions via rule-based inferences, but cannot handle complex situations. However, agent-based interfaces can describe the state of the environment (indoor and outdoor) and prompt users.

Figure 9 shows a feasible computing device (Campbell CR510 data logger) receiving data from sensors and allowing simple rule-based program design. The start of measurements and control of functions are based on time or event. The data logger is able to drive external devices, such as pumps, starters, or control valves. The data logger's programming software is known as EDLOG. EDLOG contains computing units for input and output, processing, processing control, and output processing. In addition, VB program executable files are need-

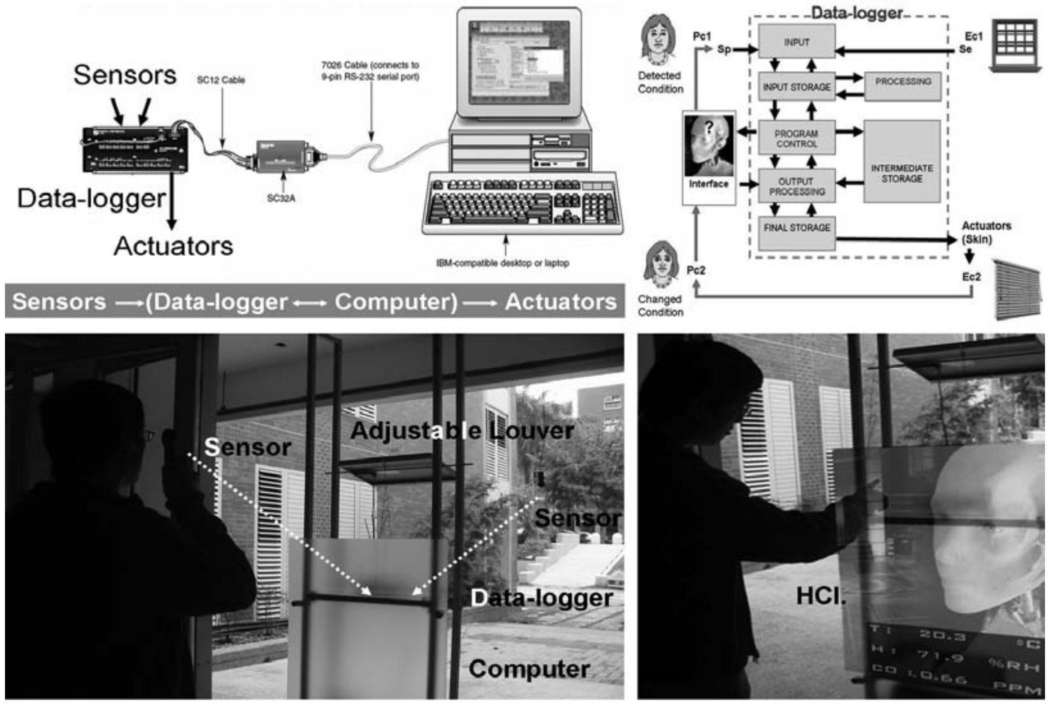


Fig 9.
A prototype smart skin

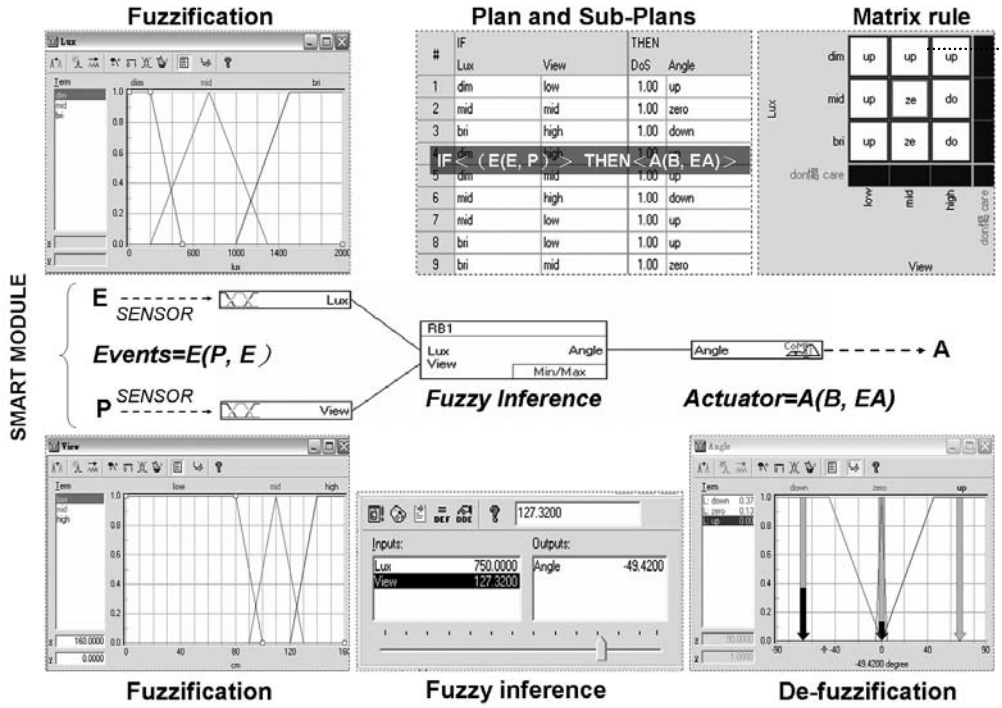


Fig 10. Fuzzy logic inference mechanism

ed to activate interface agents. Database applications programs (Dream-weaver+ ASP+ Access) can be used to design a user interface and establish a database. The figure shows indoor and outdoor light sensors. The data logger can adjust the sunshade angle on the basis of its inferences. If, however, information from the two sensors causes a logical conflict (XOR), the user must communicate interactively with the interface agent.

Algorithmic mechanisms: Fuzzy logic inference and neuro-fuzzy learning

Based on the functional definition of smart skins, a smart module-computing mechanism unit possesses at least two sensor input terminals receiving event information. Here an event refers to a person's motion in space or information generated by a person's interaction with the environment. The two sensors respectively receive information from the environment (E) or people (P). At least one terminal provides output to an actuator, and the actuator can be an in-fill component (B) or other element agent (EA).

1. The fuzzy logic inference mechanism consists of (1) fuzzification, (2) fuzzy inference, and (3) de-fuzzification. Fuzzy inference plans or sub-plans determine rules from input to output depending on detected events, i.e., IF<detect input event (E, P)>THEN<action (output)-(B, EA)>. In addition, the cause and effect relationship between the detected input and output action can be expressed as a matrix rule. (Figure 10)

2. The smart skin's neuro-fuzzy learning employs an error back propagation supervised learning algorithm, and relies on the adjust-

		THEN	
	Trans	DoS	lm
	mid	1.00	mid
	high	1.00	low
	mid	1.00	bri
	low	1.00	mid
	high	1.00	mid
	high	1.00	bri
	low	1.00	bri
	mid	1.00	mid
	low	1.00	mid
	high	1.00	bri

#	IF		THEN	
	Angle	Trans	DoS	lm
1	mid	mid	0.60	mid
2	up	high	0.50	low
3	down	mid	1.00	bri
4	mid	low	0.80	mid
5	mid	high	0.90	mid
6	down	high	0.40	bri
7	down	low	0.30	bri
8	up	mid	1.00	mid
9	up	low	0.70	mid
10	mid	high	0.80	bri

Table 2. Neuro-fuzzy learning: Adaptive DoS

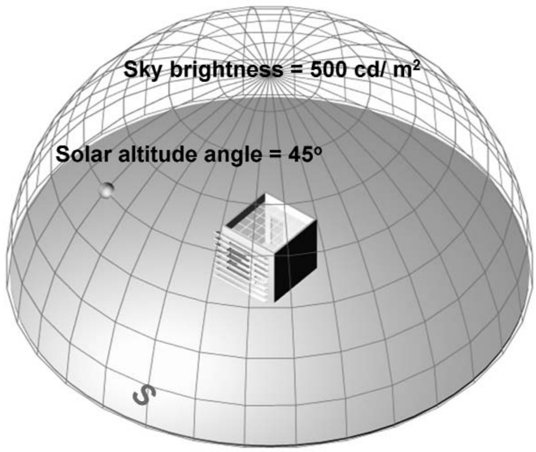


Fig 11. Environmental settings

ment of degree-of-support (DoS) to reduce the error between the predicted fuzzy inference value and the actual use value. This achieves optimized correspondence between input and output (Altrock, 1995) (Table 2).

IMPLEMENTATION OF AN AGENT-BASED SMART SKIN

The goal of this experiment is to test the ability of intelligent agents to perform tasks. This involves not just the individual actions of intelligent agents, but also the interaction of the user with an agent community.

Task and basic conditions

The main task is the adjustment of indoor lighting. Fuzzy-TECH software is used to simulate a smart skin's fuzzy logic inference and neuro-fuzzy learning. This experiment's unit modules are simplified as two input terminals and one output terminal, and linguistic terms are uniformly reduced to three (e.g., up, zero, and down, or low, mid, and high).

Setting user attributes and activities

The purpose of setting user attributes and activity type is indeed to test adaptive behavior at different smart care levels. Observations from everyday life indicate that there are two main reasons for adjusting indoor lighting. One reason the user's age: Since vision gradually deteriorates with age, older users need illumination to perform various activities. The second reason is the lighting need of the activity that will occur. Different activities require different illumination. The adaptive behavior that occurs when an agent outputs a smart care level can be seen as a response function to the user's age and the lighting need of the activity. This is to say: IF event = (user age, lighting need of the activity) THEN action F = (user age, lighting need of the activity).

User attributes consisted of adults over 30 years of age and seniors less than 70 years of age; the 30 persons included equal numbers of men and

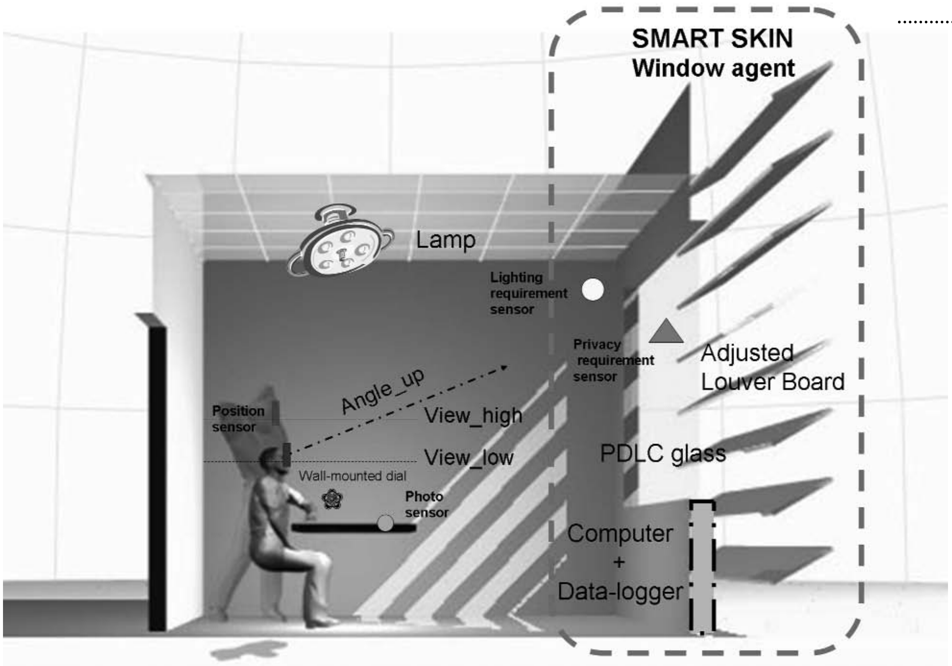
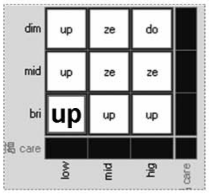
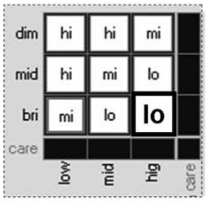
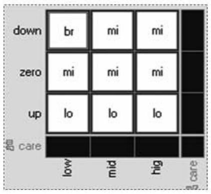


Fig 12. Experimental room

Table 3. Fuzzy inference plan

	Input IF <E(P, E)>	Output THEN <A(B, EA)>	Matrix Rule
Window Agent			
L B Agent	Lux_dim=(1/0, 1/200, 0/500) Lux_mid=(0/200, 1/750, 0/1300) Lux_bri=(0/1000, 1/1500, 1/2000) X View_low=(1/0, 1/90, 0/100) View_mid=(0/90, 1/110, 0/130) View_hig=(0/120, 1/140,1/160)	Angle_Down=(1/-90,1/-45,0/0) Angle_Zero=(0/-5,1/0,0/5) Angle_Up=(0/0, 1/45, 1/90)	
PDLC Agent	Lux_dim=(1/0, 1/200, 0/500) Lux_mid=(0/200, 1/750, 0/1300) Lux_bri=(0/1000, 1/1500, 1/2000) X Privacy_low=(1/0, 1/200,0/300) Privacy_mid=(0/200, 1/300,0/400) Privacy_hig=(0/300, 1/400,1/500)	Trans_low=(1/0, 1/30, 0/50) Trans_mid=(0/30, 1/50, 0/70) Trans_hig=(0/50, 1/70, 1/100)	
Lamp Agent			
	Angle_Down=(1/-90,1/-45,0/0) Angle_Zero=(0/-5,1/0,0/5) Angle_Up=(0/0, 1/45, 1/90) X Trans_low=(1/0, 1/30, 0/50) Trans_mid=(0/30, 1/50, 0/70) Trans_hig=(0/50, 1/70, 1/100)	Im_low=(1/0,1/200, 0/500) Im_mid=(0/300,1/900, 0/1500) Im_bri=(0/1200,1/1800, 1/2400)	
Database Agent			
	Used Record of Lighting	To Learning Agent	
Learning Agent			
	Training set data from Databased Agent	Dos values are adjusted	

women. In line with smart care level, the occupants were classified as normal, healthy seniors, and disabled persons. The lighting needed for the occupants' activities was classified as dim (relaxation-resting, chatting), medium (general tasks- reading, writing), and bright (precision tasks- sewing, nursing care). In addition, activity privacy needs were classified as low (talking), medium (reading, writing, sewing), and high (resting, nursing care).

Environmental settings and implementation

This experiment used a window agent as a smart skin, and investigated the possibility of interaction between smart skins and other intelligent agents. The experiment was conducted in a 3.6X3.6X3.6 m3 indoor space. Light was obtained through a south-facing window; the solar altitude was fixed at 45°, and the sky brightness was set at 500 cd/m2 (Figure 11). The sill height was 90 cm above the floor, and the window opening was 2.7X1.8m2 (w, h). Furniture was temporarily arranged around the room to facilitate the experiment. (Figure 12)

The window agent consisted of two subagent module elements: a louver board (LB) agent and a polymer-dispersed liquid crystal (PDLC) glass agent. The louver board agent adjusted the louver angle (down, zero, up) in accordance with indoor lighting needs (dim, mid, bright) and the user's visual needs (low, mid, high). The PDLC glass agent served to adjust the transparency of the PDLC glass in accordance with the indoor activity lighting needs (dim, mid, bright) and the user's privacy needs (low, mid, high). The fuzzy inference plan was as shown in Table 3. For instance, if the lighting need was high (bright) and visual need low, the louver board would be adjusted up for more sunlight and visibility. Furthermore, the system interacted with another smart entity- a lamp agent. The system received information from the window agent via wireless signals, and adjusted lamp brightness in order to improve indoor illumination. In addition, the user could use a wall-mounted dial to adjust the lighting. The learning agent used a neuro-fuzzy training data set from the lamp use database to adjust the

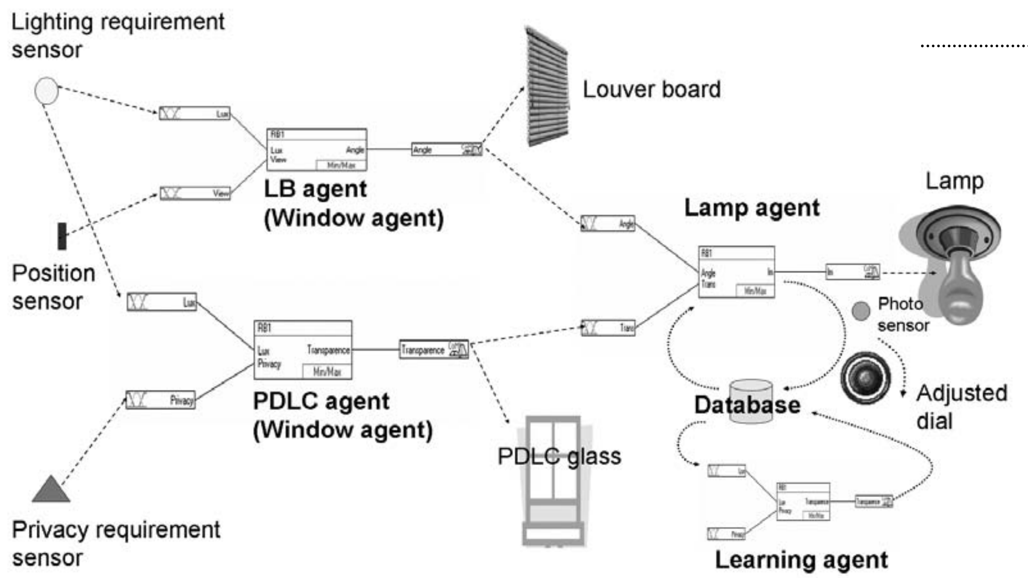


Fig 13.
Interaction and cooperation in an agent community

DoS of the lamp agent's fuzzy inferences and improve the lamp agent's predictive ability.

In accordance with its mission and overall goals, the experience analyzed the following four types of interactive relationships possessed by agents and societies: (1) Agents of the same type may perform different tasks with different goals. (2) Agents of the same type may perform tasks with the same goals. (3) Agents of different types may bear responsibility for sub-tasks with the same goal. (4) Agents of different types may perform sequences of different tasks with the same goals. Although the louver board agent and PDLC glass agent are both window agents, the former adjusts visibility and the latter controls privacy. They thus control different window functions, and can be seen as (1) agents of the same type performing different tasks with different goals. But from another point of view, since they both affect the lighting needs of the user's activities, they can be seen as (2) agents of the same type performing tasks with the same goals. In contrast, although the louver board agent and lamp agent are different types of agents, they constitute (3) agents of different types that bear responsibility for sub-tasks with the same goal, namely the goal of lighting. The communication and cooperation from the lamp agent and database to the learning agent constitutes (4) agents of different types performing sequences of different tasks with the same goals (Fig. 13).

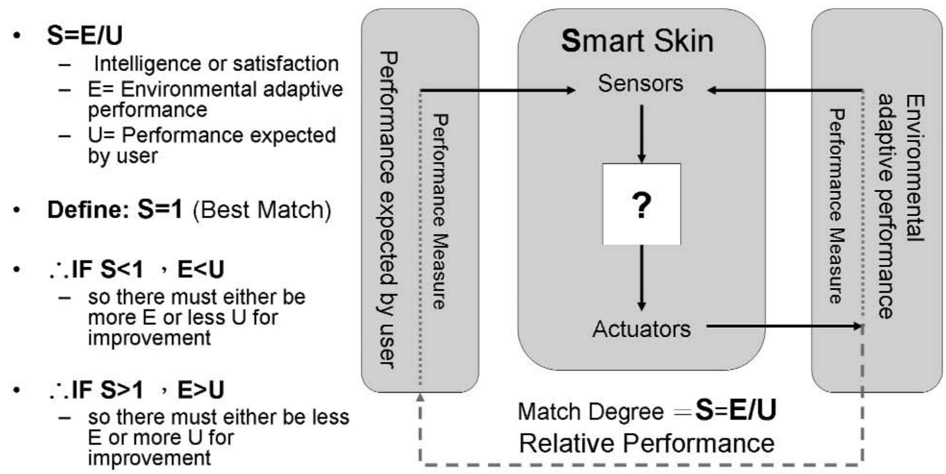


Fig 14.
Relative performance

Assessment of relative intelligence and performance:

The relative performance assessment method is adapted from the performance measure concept (Russell, 2003: 32-58), and serves as a user-oriented assessment indicator (Figure 14). Relative performance is a measure of the agent's intelligence; in other words:

Intelligence = user satisfaction = adaptive performance ÷ performance expected by user = relative performance

The window agent must provide proactive assistance when the users are, for instance, elderly or mobility impaired. Suppose the initial illumination is 500 Lux, and the agent changes this to 1,000 Lux after performing inference. The adaptive performance is therefore 1000-500?500 Lux. If user A feels that the lighting is just right, and there is no need to adjust the illumination, the relative performance is therefore (1000-500) / (1000-500) ?1. If, however, user B uses the dial to change the illumination to 1,300 Lux, the relative performance will then be (1000-500) / (1300-500) ?0.625. The adjustments and relative performance values are recorded in the use database. It was found that relative performance tended to be lower when users were middle-aged or older (40-65 years of age or above). Results suggest that the elderly have greater illumination needs than most normal adults.

RESULTS AND DISCUSSION

The foregoing illustrates how intelligent agents can use fuzzy logic inference and neuro-fuzzy learning. The following are some feasible suggestions:

- The system may be combined with other open building systems: While this study addressed only parts of building shells, in fact open buildings also include open living, open supply, and open production systems (Tatsumi, K., 2000: 40～43), along with these systems' derivative in-fill components.
- Establishment of a prior knowledge database: Predictions are based on user preferences and habits, which are reflected in fuzzy inference plans or sub-plans, or in distribution of DoS. Prior knowledge is a prerequisite for fuzzy inference. For instance, before establishing a matrix rule for the louver board agent, it is necessary to know that people usually open the louver window to obtain more light to increase the visibility when the need for illumination is high. Further research should deal with people's spatial perceptions and environmental behavior to scientific analysis.
- Smart care functions: In-fill component adaptation records can provide a better understanding of occupants' use or health. For instance, the fact that a smart skin's louver window is usually closed may indicate that a space is currently often used for resting. On the other hand, the fact that the PDLC glass is usually not transparent indicates that the indoor activities require a high level of privacy, which may lead to the conclusion that the occupant is ill and needs more rest.
- Conflict resolution: The events perceived by agents and the tasks and target benefits of agent societies are not necessarily identical. Cooperation and compromise in the case of conflict depend on reasonable inferences by the fuzzy inference plan. Taking the PDLC glass agent as an example, the occupant's illumination needs will be high (bright) when he or she is receiving nursing care, but he or she will also have a high need for privacy. In this case, should the PDLC glass increase transparency in order to admit more light? Or should it reduce transparency in order to provide more privacy? For instance, as can be seen from the second column of Table 3, when IF ?Lux (bright) and Privacy (high) ? THEN ?Trans (low) ?, the agent will reduce the transparency of the PDLC glass to increase the occupant's privacy. But since there will be little natural light in the room, the lamp agent will then adjust the lamp brightness to provide the illumination needed for nursing care.
- Comparative analysis of the open building and smart open house concepts (Table 4).

Item	Open Building	Smart Open House
Topics	Industrialized house Variation = (time + architecture)	Addresses new contemporary issues Adaptation = intelligence × (time + architecture)
Period issues	Systematic construction method: 1960s: modular grid used to coordinate layout Late 1970s: open construction, support design pursuing economic effectiveness 1980s - 1990s: realization of commercial In-filled systems, e.g., Matura, Esprit 1990s: sustainable construction interface design	1. Sustainable construction 2. Response societal aging
Problems faced	1. Need for individual diversity and local variations under industrialized production. 2. Need to reflect changes in occupants, use functions, and content in the building life cycle.	1. Sustainability and health: Need to optimize occupants' health and comfort, sustainability, and environmental changes 2. Aging society: Need to use adaptive architectural elements to realize smart care design features.
Design goals	To introduce individual diversity under industry production	1. To optimize needs and change 2. To employ smart care features to help users to maximize independent living
Systems integration	Integration of open living system, open supply system, and open production system	Integration of smart open system and open building system
Constituent elements	Support + in-filled components (structure, floors, doors & windows, furniture, etc.)	Intelligent agents (including software and hardware, sensors, computer, actuator)
Levels	Support and in-filled components	User-oriented smart care level:(1) Ordinary people, (2) Healthy seniors and (3) Disabled persons
Behavior	Changes in a building's in-filled components; movements include configurations of morphological grammar: translation, rotation, replication, reflection, etc.	Adaptive actions include: passive, reactive, proactive, interactive
State changes	Interaction of building's life cycle and user's living behaviors	Lifetime use; reacts to events; adaptive actions
Communication platform	Common management and communication	Communication protocol, human-computer interface
Assessment standards	Capacity	Relative performance
Design process	Participatory design	User-oriented; human-machine interaction
Construction management	Two phases of construction (support and infill)	Smart open system can be updated at any time

Table 4. Comparative analysis of open building and smart open house concepts

CONCLUSIONS

This study proposed the use of intelligent agents to establish a smart open system in a distributed intelligent environment. This smart open system possesses autonomy and smart open modules and can perform adaptive behavior, further realizing the flexibility and variation of open buildings.

Existing data logger technology was used in this study to verify the establishment of a rule-based agent-based smart skin. Although the smart skin could handle simple situations, because no fuzzy logic-based data logger was available, software was used to test the theoretical feasibility of a fuzzy logic smart skin system, and a user experience-oriented smart mode and assessment mechanism were derived. Future research should focus on practical applications involving hardware and software integration.

An individual intelligent agent can define the three user experience-oriented smart care levels of (1) Ordinary people, (2) Healthy seniors and (3) Disabled persons depending on whether there is human-computer interface prompting and agent's adaptive behavior mode. And agent societies can generate interactive behavior reflecting the agents'

similar or different tasks and goals. In conjunction with rule-based inferences and artificial neural network learning, fuzzy logic and neuro-fuzzy technology can enhance the system's reasonableness, reliability, and predictive ability. It can be foreseen that agent-based smart homes will be widely used in the aging society of the future. Thanks to their user experience-oriented smart care features, these homes will meet occupants' lifelong needs and provide greater residential comfort, safety, and health.

ACKNOWLEDGMENT

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REFERENCES

ALDRICH F. K., 2003, Smart Homes: Past, Present and Future, Richard H. (ed.), 2003, *Inside the Smart Home,* Springer-Verlag London, pp.17-18

ALTROCK, C. V., 1995, *Fuzzy Logic and Neuro Fuzzy Applications Explained*, 3rd Chinese translation edition, 2005, Scholars Books, Taipei

CHEN, J. H., 2006, Comprehensive Planning for the Coming of Aging Society in Taiwan: A vision for the First Quarter of the 21st Century, Mid-term report, the NSC 94-2420-H-033-001-KF, pp. 87

CHEN, S. Y., M.L. CHIU, 2005, Toward smart envelopes: an agent approach for environmental awareness in houses, The 2005 World Sustainable Building Conference in Tokyo, *Proceeding of SB-05 Tokyo*, CD-ROM, No. 07-008, pp 2379-2386

HABRAKEN, N. J., 2000, The Open Building Approach: Examples and Principle, Wang, M. H. (ed.), 2000, *Selected Papers on Open Building: Toward User Friendly Building Industry,* The Architectural Institute of ROC., pp. 9-10

HABRAKEN, N. J., 2000, Support and Infill: Design and Implementation, Wang, M. H. (ed.), 2000, *Selected Papers on Open Building: Toward User Friendly Building Industry,* The Architectural Institute of ROC., pp. 59-72

HSIEH, Y.H., 2005, *A variable research on ageless house depending upon the physical and mental status of the aged-Taking Tou-tain-cuo as an example,* Master thesis, The graduate school of Architecture, Chung Yuan University, Taiwan, pp 3-1, pp. 3-9

LIN, L. C., 2002. *Architectural Construction Theory on Open Interface,* Ph.D dissertation, The graduate school of Architecture, National Cheng Kung University, Taiwan, pp. 10

MAHDAVI, A., 2005. Sentient Buildings: from concept to implementation, in Chiu, M. L. (ed.), *Insights of Intelligent environments,* Archidata, pp. 45-66

MINSKY, M., 1988, *The society of mind,* Simon & Schuster, Inc., pp. 34-35.

MOZER, M. C., 2005, Lesson from an adaptive Home, D. J. Cook and S. K. Das (eds.), *Intelligent environments,* John Wiley & Sons, Inc., pp. 273-294

NEGNEVITSKY, M., 2005, *Artificial intelligence A Guide to Intelligent System,* Second edition published, Person education, Ltd, pp. 87～127, 268-284

PADGHAM, L. AND M. WINIKOFF, 2004, *Developing intelligent smart open system systems a practical guide,* John Wiley & Sons, Ltd, pp. 1-20, 55

PAL, S.L., S. C. K. SHIU, 2004, *Foundations of Soft Case-Based Reasoning,* John Wiley & Sons, Ltd, pp. 231-252

RUSSELL, S., & P. NORVING (eds.), 2003, *Artificial intelligence A modern Approach* (2nd ed.), Pearson Education, Inc., pp. 32-58

TATSUMI, K., 2000, Toward a Development of The Open System for Multi-Unit Housing, Wang, M. H. (ed.), 2000, *Selected Papers on Open Building: Toward User Friendly Building Industry,* The Architectural Institute of ROC., pp. 40-43

WOOLDRIDGE, M. J., 2002, *An introduction to Multi-Smart open system Systems,* John Wiley & Sons, Ltd, pp.23-25

WEBSITES

Adaptive House, http://www.cs.colorado.edu/~mozer/nnh/

Aware House, http://www.gatech.edu/innovations/future-home/index.php

House_n , http://architecture.mit.edu/house_n/

Toyota Dream House PAPI, http://tronweb.super-nova.co.jp/toyotadreamhousepapi.html

TRON intelligent house, http://tronweb.super-nova.co.jp/tronintlhouse.html

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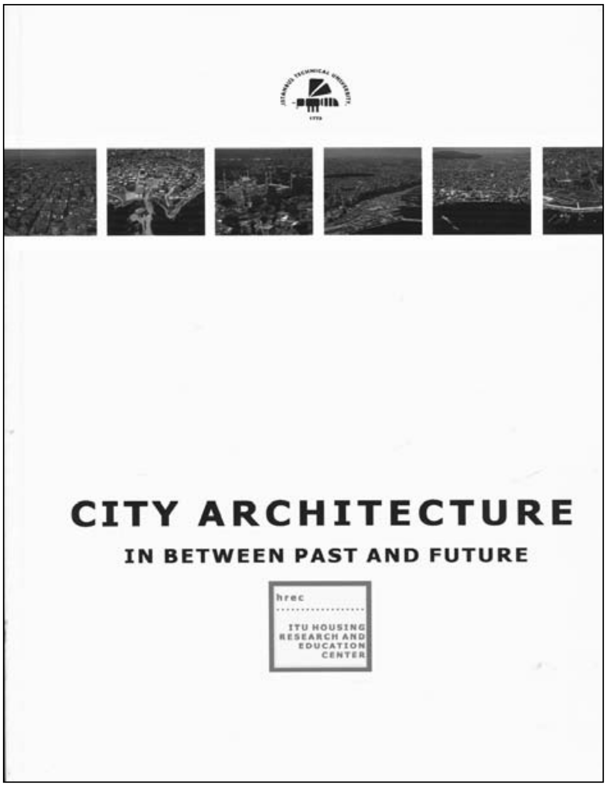

The book anthology represents a compendium of papers delivered at the second of two international workshops conducted during the summer of 2004 at the Istanbul Technical University, Housing Research and Education Center. The thematic mark is to explore a generic city of opposites. In thirds the groupings of conference delivered papers reflect theory, case studies, and the concentrated analysis of a 700-year old Ottoman Village in Turkey. The latter focus on the town of Cumalikizik presents the threat of modernization to its significantly redeeming historic and architectural qualities.

At times, the papers and their editorial introductions present themselves obtusely, leading me to believe that architects should not write and reaffirming my admiration for them as design professionals. Indeed, replacing a picture with a thousand words can be either enlightening or demoralizing. I cannot fathom the abstractions of "permeable, resilient and transparent urban forms," or just how to manage "mass-void relationships." Yet, apparently, they do make a place "responsive."

Aside from my personal struggle with the lexicon of visionary concepts, the series of papers seemed as disjointed as the intentions of central theme. Several hit the mark while others did not appear as a sequence. Both the theoretical concepts and the series of case studies appear as stand-alones; there is no point and counter-point and no progression of, for instance, general to specific or through the design process. An anthology's pitfall is that the pieces fail to have a conversation with each other, despite their commission to do so.

Nevertheless, I found fascination with the irony of the harmony of dissonance. As a sub-theme, 'in between past and future" is explored in the opening paper by Karen Franck through the juxtaposition of new and old urban forms. The duality of her interest is in the ambiguous as well as the "clarity of oppositions."

In sum, the incongruity of city forms, historic and contemporary, a variety of styles, scale, even full sensory messages, promotes the city as both legible and interesting. Opposites both repel and attract. The dissonance is appealing.

The message to planners and urban design professionals promotes the value of heterogeneity. Boring is homogenous environments, as if "planned" or designed through a unified, uniform vision. Yet, it seems that a consonant harmony prevail the professional culture. This anthology presents the challenge to such conventional thought.

Where have we seen this before? Outside the literacy of the design professions is anthropology, and

the memorable work of William Whyte [The Organization Man, 1956; The Last Landscape, 1968; and his capstone achievement in City: Rediscovering the Center, 1988], who systematically observed how people behave with urban form. In sum, the congregate person loves the tension of urban life. Whyte understood the ironic appeal of opposites, of dissonance that makes imperfectly human and worthy of human interest our built environment.

I reflect on my own emotional experience with New York City subways at rush hour. The train car treated passengers as canned sardines, forcing most to stand, struggling to counter-balance the train's erratic motion, and be "uncomfortably" close to strangers. However, that discomfort yields to a voyeur's fascination, the privacy of anonymity, and the security of numbers. The juxtaposition of opposite sensory receptions compels many to the urban, congregate, life style.

Of the twenty-four contributors to this anthology, all are architects or urban planners, a limiting factor. Notable strides have been made by the likes of Whyte, as an anthropologist and writer for the popular press [The New Yorker] and Jane Jacobs, as the "nonprofessional" savior of the old urbanism.

A shortcoming of the editing, the book deserves an index and list of illustrations. The illustrations are replete throughout and on paper stock suited to full color publication. Yet, without text wrapping there are unnecessary gaps on the page. We are left with the impression of a less than professional publication.

As the editors' "last word": *The editors of this book hope that this one tempts further inquiries into the city and life from architectural and contextual point of view in order to generate more conscious and more people-responsive, integrated urban environments…, and protecting their original patterns while encouraging the piecemeal growth.*

I do commend the book to design professionals, primary, and to the lay public interested in urban form, secondarily. But, most of all I commend the editors' hope to other scholars.

Notes to Authors

Manuscript formatting requirements

All manuscripts must meet the following requirements:

1. The title of the paper should not exceed ten words.
2. There must be an abstract of between 200 and 300 words.
3. The manuscript must have a maximum of five keywords following the abstract.
4. The manuscript must have a reference section at the end with the author's names in upper case followed by the year, the title of the reference in italics and the source or publisher in normal lower case e.g JACKSON N.1999, *Reconstructing Architecture for the Twenty First Century*, Toronto University Press, Toronto, Canada. In this case the whole book/article is being referred to i.e no pages numbers are given.
5. The citation format in the body of the text must have the author's name in lower case followed by the year in brackets e.g (Hamdi N.1999). Where a specific page or pages are being referred to then the page number or numbers must be cited after the author's name e.g (Wills, 2002:31. or Wills 2002:31-44)
6. There must be a conclusion at the end of the manuscript.
7. The length of the manuscript should be around 4000 words .
8. All illustrations must be stored on a separate file to the text.
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10. All photographs, maps and graphs must be in **TIFF** format and not be less than **300 dpi**. Photos should be scanned as multi-colour (8 bit colour) and then transferred to grey scale. Width=12cm, the height is free.
11. All tables, graphs and line drawings should be in rich text form or .doc format using Word, Power Point or Excel original programs. Please only use grey scales (no colour).
12. In the first instance and for refereeing purposes send a copy of your article to the Editor with all images embedded in the text in **PDF** format to the Editor in Chief.
13. For the final submission i.e after refereeing and revising of the manuscript please ensure that all illustrations whether tables, graphs, photographs, maps or line drawings must NOT be embedded in the text of an article. Authors MUST put all illustrations on a separate file and only put the figure number with caption in the text to show where the illustration should be. Any article which does not follow this guide line will not be published.

Finally when the manuscript is cleared for publication it must submitted on a CD (text and images on separate files please) and sent to the following address. Nicholas Wilkinson, Eastern Mediterranean University, Faculty of Architecture, Mersin 10, Turkey
14. With the CD send one hard copy of the text **without** images and one copy **with** images in the text.
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